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RHYTHM.

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INTRODUCTION.

Although experimental psychology began more than a hundred years ago through the discovery of the personal equation, it has as yet covered but a small portion of the field of mental phenomena. The nature of sensation, the time-relations of mental phenomena, memory, association, space and time concepts have been carefully studied by many eminent scientists. But the whole field of the emotions has been practically a *mare clausum* for psychologists. Several attempts to study and determine the nature of the simplest æsthetic forms have been reported; theories of pleasure and pain, supported by some experimental observations, have been advanced, but no serious attempt has been made to submit the emotions to experimental investigation. Every psychologist recognizes the necessity of doing so and that it is the most important field of mental phenomena, and that, until psychologists can reduce the motions to some semblance of order or more ultimate principles, experimental psychology can be said to cover only a part of the field of mental life. Every one is waiting for some one else to point out the way. There seems to be a general feeling that when once an entrance has been effected, the greatest difficulty will have been

surmounted and the whole field will yield to experiment. In a measure this is the true view to take, and yet certain of the emotions are as distinctly separated from others as the whole field is from that of the memory.

When the demand for such a study is so great, and students are being urged to make a trial, that one who does attempt it, though he fail, cannot be accounted rash.

The experimental study of rhythm which is to be presented in this paper, is an attempt to push the lines of exact science a little farther forward into a field that borders more closely upon the field of æsthetics than any other that experimental psychologists have tried. The attempt is to be made to reduce rhythm to a more fundamental activity of mind. The pleasure that individuals take in the rhythmic flow of words and sounds has been ascribed by one to the "Unifying Activity of the Feelings," by another to a "Sense of Order," and by still another to "The Feelings of Equality." Such explanations as these do not meet the question at all, unless it can be shown that such activities or feelings are ultimate facts of mind. If they are ultimate facts of the mind, it will be necessary, in order to make the explanation complete and valid, to show how they underlie other activities, for it is not to be supposed that any fundamental activity will manifest itself in a single phenomenon which bears no relation to other phenomena. Such does not seem to have been done by those who have offered explanations of the rhythms in speech, and the problem remains just where it was taken up. To regard rhythm as the manifestation or the form of the most fundamental activities of mind, seems a clearer view and to offer less difficulties than to regard it as an ultimate fact in itself. The problem, then, is to show how and to what extent it underlies mental activity, and, as preparatory to this, what part it plays in physiology and nature. Is there not some universal principle which is adequate as an explanation of rhythm in general?

Rhythm is so universal a phenomenon in nature and in physiological activity, and underlies so completely speech, that I desire to call attention to some of its manifestations in detail before presenting the experimental study.

Rhythms in Nature:—Natural phenomena very generally, if not universally, take a rhythmic form. There is a periodic recurrence of a certain phenomenon, sometimes accompanied by others, going on continuously in all that pertains to nature. Motion, whether in the broader field of the universe or upon the earth, is very generally periodic. Light, heat, sound, and probably electricity, are propagated in the form of waves. A falling body does not follow a straight line,

neither does a rifle bullet describe a simple curve which is the resultant of the combined forces of gravity and the initial velocity. Mr. Herbert Spencer has treated this subject in his "Principles of Philosophy" at considerable length, and has left but little that can be said here. Although he does not say so in so many words, he seems to hold that it is the only possible form of activity; continuous motion is an impossibility.

The cosmic rhythms, however, are the most fundamental and important of natural phenomena. They may be shown to underlie in a measure and be the cause of many other rhythms in plant and animal life. The regular alternation of light and darkness due to the rotation of the earth upon its axis is the most striking rhythm in the cosmos. The two periods of light and darkness constitute a unit — the day — which remains always the same in length. Days are grouped into months by the revolution of the moon about the earth, and into years by the revolution of the earth about the sun. These periodic changes have had a tremendous influence upon animal and plant life, and have stamped their impress upon all living organisms in the most striking manner; some, however, upon certain organisms more than upon others. In the vegetable kingdom some plants show a daily growth and repose; their flowers bloom in the morning and close before the evening. Some turn their petals towards the sun, and make a daily revolution in order to keep them so. In certain latitudes all vegetation shows normal periods of growth and fruitage which are not necessarily cut short or lengthened by early or late frosts. It requires a certain time for development without regard to the character of the season. The lunar period is known to influence the blooming of flowers. A species of Chinese roses blooms with a monthly regularity during the season.

The influence of these cosmic rhythms is not less upon the animal kingdom. The daily rhythm causes the daily periods of sleep and waking, from which no terrestrial creatures of the higher types are exempt. The periods of sleep and waking are not determined by the effect of light and darkness as are the movements of many plants. The lunar period has had a far-reaching effect upon animal creatures, especially as regards reproduction and the nervous system. The periods of gestation and the recurrence of heat and menstrual flow in both human beings and animals bear a very close and striking relation to the lunar period. The period of gestation in some lower mammalian animals is one month. In the higher forms it is a certain number of months. The time of incubation is with some species of fowls a month, but it seems to

conform in general to a period of days which is a certain multiple of seven, seven being one-fourth of a lunar month. Fourteen, twenty-one and twenty-eight days are very common periods of incubation. The year exercises a still wider influence upon the animal kingdom. The normal life of most species of insects terminates in a single year. The frog becomes nervous and irritable with the approach of spring, although the conditions under which it is kept may not change. The polar bear goes into hibernation, even though he has not made the proper preparation in the way of a store of fat. The migrations of birds are not necessarily prompted by the signs of approaching winter. Animals breed generally in the spring—a fact which cannot find sufficient explanation in the influence of a warmer temperature. It has been fairly established that growth is more rapid during the summer months.

Although we find that these cosmic rhythms have stamped themselves upon the organism more or less permanently, they have wielded a far mightier influence upon the minds of men. Among primitive peoples that were rich in imaginative power, they have given rise to the most elaborate and beautiful systems of mythology and worship that the world has ever seen. It is a common speculation in childhood that, endowing animals at birth, as children do, with rational intelligence, but with a total lack of experience, the young creature must be driven to strange thoughts and speculations when the first light of day breaks in upon him, or when darkness approaches for the first time. What can be the thoughts of such a creature when he experiences the change of seasons or the first snow storm? No objects that are presented to the child so stimulate his thought and become such food for his fancy as the heavenly bodies and cosmic phenomena. Many of their minds are filled with myths about the stars that are as original and beautiful in conception, though lacking in detail, as much of the Greek mythology.

The recurrence of the day of the year upon which some event has happened is commemorated as a day of joy or sorrow according to the nature of the event. All national and religious festivals recur once a year. Among primitive peoples worship takes place always at the same time of day or year, and the same might be said of most enlightened people. There seems now, and always has seemed, a peculiar appropriateness in performing certain duties at the same time of day or year, although it does not necessarily depend upon the nature of the weather or of the event. The Christian Sabbath and other religious festivals, both savage and civilized, find their origin in the nature worship of the sun and the moon.

There are still other rhythms in the cosmos which seem to exercise an influence upon mankind. Sun spots make their appearance in great numbers once in about eleven years, and the attempt has been made to connect these with great financial disasters and religious awakenings which seem to recur in the same time. The social customs of the race show similar changes, which may prove to have some connection with sun spots. The coincidence warrants an investigation and allows speculation.

Upon the morbid side science has made discoveries of the most striking character. Even from the earliest times a periodicity has been observed in certain forms of insanity and in other mental diseases. These have been confirmed by later investigations.[1] Both crime and suicide show a periodicity which corresponds with the year, and another which corresponds to the larger period of sun spots.

Physiological Rhythms:—No fact is more familiar to the physiologist than the rhythmic character of many physiological processes. In physiology it means the regular alternation of periods of activity and periods of repose or of lesser activity. The term is also applied to any alternation of activity and repose, whether it is regular or not. These periods of activity and intervals of repose may succeed one another at very small intervals of time, as in the case of a clonic contraction of the muscle, or at very much greater intervals, as in the case of sleep and waking, or better still, in the periods of growth in children. Several of the most vital and important bodily activities are distinctly rhythmical, and will serve as types of all physiological rhythms. Of these, might be mentioned the pulse, respiration, walking and speech. The first two are involuntary actions, which in the very nature of the organism must be more or less rhythmical. Such actions are controlled by the lower nerve centres, and the organs concerned in them are connected in a reflex arc with these nerve centres. Habits are in the nature of involuntary actions. Of these, walking and speech are the most important and are true types of rhythmical activity. In each there is a series of coördinated muscles in which the contraction of one is the signal for the contraction of the next in the series, the last acting as a stimulus to the first.

Independent of the regular beat of the heart and forming a kind of higher grouping of these beats, the arteries undergo continuously rhythmical contractions and dilations of their

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[1] Dr. Koster, "Uber die Gesetze des periodischen Irreseins und verwandter Nervenzustände." Bohn, 1882.
Dr. Ludwig, "Periodischen Psychosen." Stuttgart, 1878.

walls, now increasing and now decreasing the blood supply. These may be observed with a glass in the arteries of a frog's foot or a rabbit's ear, occurring about once a minute. They may be made to cease entirely by cutting off the nerves going to these organs.[1] These arteries are controlled by the vaso-motor system, and the rhythmic contractions of the arteries seem to indicate a rhythm in the activity of the nerve centres. As we shall see later, there is some ground for believing that all nervous action is rhythmical. Regular contractions occur in the heart of some animals after they have been removed from the body, and are found to be due probably to the presence of nerve ganglia in these organs.[2] The effect of deficient arterialization upon the vaso-motor system is to cause a rise in the curve of blood pressure. This curve, then, shows certain undulations, which have been called Traube-Hering curves, from their discoverer. This result is obtained by cutting the vagi nerve and stopping respiration. The venus blood then acts as a stimulus upon the vaso-motor centres in the medulla, which causes these rhythmic movements. "This rhythmic rise[3] must be due to the rhythmic contraction of the arteries, and this is caused by a rhythmic discharge from the vaso-motor centres." "The vaso-motor nervous system is apt to fall into a condition of rhythmic activity." A similar phenomenon has been thought to be observed in regard to the spinal cord.

When the spinal cord[4] of a dog, cat or rabbit was cut, rhythmical contractions of the sphincter ani and of the vagina appeared. These contractions vary in number, but are generally about twenty per minute for the sphincter ani and four per minute for the vagina. The centre for these contractions was found to be in the spinal cord, about the level of the sixth and seventh lumbar vertebræ in rabbits and of the fifth lumbar vertebra in dogs.

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[1] Foster's "Physiology," 6th Ed. p. 307.

Dr. Ellis, working under Dr. Bowditch, has studied these contractions in the web of a frog's foot with the microscope. He says that cutting the sciatic nerve does not stop them, and concludes that they are due to peripheral centres, unless he be allowed to suppose that automatic contractility is a property of smooth muscle tissue. Plethysmographic and vaso-motor experiments with frogs. *Jour. of Phys.* Vol. VI. No. 6, p. 437.

[2] Foster's "Physiology," 6th Ed. p. 357.

[3] Foster's "Physiology," 6th Ed. p. 622.

[4] Isaac Ott, "Observations upon the Physiology of the Spinal Cord." Studies from Biol. Lab. at Johns Hopkins University. No. II.

Fatigue shows itself to be a rhythmical process. Dr. Lombard[1] worked upon the flexor muscle of the second finger. After contracting the muscle several times, lifting each time a weight, he gradually lost the power of further contraction, but he continued to make the effort at regular intervals of two seconds. In a short time he regained his former power, which he maintained for several minutes, and then gradually lost it again. About five periods of alternating loss and recovery took place in twelve minutes. By variations in the methods of experimentation, the different factors are eliminated, and he is able to conclude that the centre of voluntary control is unaffected, but that this periodicity is dependent upon "alterations which take place in some of the mechanisms between the areas of the brain originating the will impulses and the centrifugal nerves." Dr. Hodge[2] found that when he stimulated the spinal ganglia of a cat continuously with an interrupted current, no change of the cell took place. When he applied his interrupted current for a quarter of a second and allowed the cell to rest three-quarters, a change took place in the nucleus of the cell. These experiments are inconclusive, as in the first case the animal was given curari and in the second it was not. Dr. Burgerstein[3] tested a number of school children by their ability to multiply and add figures for four successive periods of ten minutes, with five minutes' interval between the periods of work. During the third period there was a marked falling off in the amount of work accomplished and an increase again during the fourth period. He argues that the pupils became fatigued during the first two periods, and that the third was a period of recovery, since the normal amount of work was shown again in the fourth.

The secondary rhythm observed in the circulation occurs also in respiration. Under ordinary circumstances respiration follows a rhythm of about fifteen or twenty a minute. During certain diseases and sleep a secondary rhythm—Cheyne-Stokes[4] curves—appears in respiration. The respiratory movements decrease in depth until they disappear entirely. After an interval of a few seconds a slight movement occurs. This is followed by others, which increase in strength until they become normal and sometimes abnormally strong. Two explanations are offered: first, a waxing and waning in the nutrition of the respiratory centres, and second, a rhythmic

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[1] Warren P. Lombard, M. D., "Effect of Fatigue upon Muscular Contractions." Amer. Jour. of Psy. Vol. III.

[2] "Microscopical Study of Changes due to Functional Activity in Nerve Cells." *Jour. of Morphology*, Vol. VII.

[3] Die Arbeitskurve einer Stunde. *Zeitschr. f. Schulges.* IV. 9, 10.

[4] Foster's "Physiology," 6th Ed. p. 605.

increase and decrease in the inhibitory impulses playing upon the centres. The latter explanation is favored. This, however, simply assigns the rhythmic action to some other centre and does not explain the phenomenon. A certain amount of secondary rhythm takes place in the breathing of hibernating animals. Respiration appears almost to cease and then to start again, but it is generally slower during hibernation.

Growth appears to take place rhythmically. Distinct periods of activity and rest occur in the embryonic development of some species that have been observed. This has been seen in the segmentation of pulmonates' eggs.[1] It is no less true of the amblystoma. In these the periods of activity last from five to fifteen minutes, and are succeeded by intervals of repose lasting about forty-five minutes. The activity of the protoplasm offers a resistance which must be overcome by the energy arising from the assimilation of the granular food material, which disappears as development proceeds. During the period of repose the energy is accumulating from this assimilation, which, when it becomes sufficient, overcomes the resistance, and activity sets in. This is taken to be a type of physiological and nervous activity, which will serve to explain certain phenomena of rhythm. This rhythm in growth, which is observed in the embryonic development, is characteristic of the physical and mental growth of children. For several years previous to puberty, great increase in stature is observed, puberty itself being a period of slow growth. From fifteen to eighteen is another period of growth, in which the full stature is generally reached. The mental character of children shows also periods of activity and repose.[2] The bright child becomes dull and the tidy slovenly. The leader in the athletic sports is now lazy and moping. Memory is now predominant, and now reason. The child passes from one form of activity to another. The line of development goes zigzag to its goal.

Other examples of involuntary action might be mentioned. These are the peristaltic contractions of the intestines, labor pains, the recurrence of heat and of the menstrual flow, and the secretions of the digestive cell. In these cells the secretions are kept up for about six hours, when a period of repose of about twenty-four hours follows.[3]

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[1] W. K. Brooks, "Fresh Water Pulmonates." Studies from Biol. Lab. at Johns Hopkins Univ. Vol. II.

[2] G. Siegert, "Die Periodicität in der Entwickelung des Kindesnatur."

[3] J. M. Langley and Sewell, "Histology and Physiology of Pepsin-forming Glands." Phil. Trans. Vol. CLXXII. pp. 663-711. London, 1882.

From this review it may be safely said that nervous action in general, and especially of the lower and vaso-motor centres, is rhythmical. This form of activity results from the resistance which the nervous substance offers to a stimulus. A certain amount of energy is necessary to overcome this resistance. This fact is brought out by the experiments of Helmholtz[1] and Sterling upon the summation of stimuli. Helmholtz found that when he stimulated a nerve going to a muscle by a submaximal stimulus and then added another stimulus at any time afterward within four seconds, he obtained a contraction. If he used a maximal stimulus in the first place and then added another stimulus during the latent period, it produced no effect upon the contraction due to the first stimulus. But if the second stimulus was added after the latent period, the effect was a greater contraction than that which followed the first stimulus alone. Submaximal stimuli[2] following one another, even as slow as one per second, will produce a contraction after a time. As the frequency of the stimulus increases, the effect is much more marked. It is much better to increase the frequency of the stimulus without increasing the strength than to increase the strength alone. Sterling adds further that all muscular and nervous action is due to summated stimuli—a conclusion that denies the possibility of contractions due to one instantaneous shock or at least does not explain them. Dr. Ward[3] determined that between the rates of .4 sec. and .03 sec. a contraction always followed a given number of stimuli. Above and below these limits the number might vary. In the same line is the work of Drs. Kronacker and Hall.

It has been held by Sterling and others that when a stimulus is applied directly to the cortex, no matter what the rate, the brain sent out rhythmic impulses always at a constant rate. Dr. Limbeck[4] conducted a series of experiments upon the brain and spinal cord, in which he finds that the brain and spinal cord send out just as many impulses as they receive. Faster rates than thirteen shocks per second for the cortex and thirty-four for the cord, gave smooth curves.

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[1] Helmholtz, "Berichte der Berliner Akad." 1854, p. 358.

[2] W. Sterling, "Uber die Summation electrischer Hautreize." Berlin. Berichte d. Sachsgelschaft d. Wissenschaft. December, 1874, p. 372.

[3] Dr. Ward, "Uber die Auslosung von Reflexbewegungen durch einer Summe schwacker Reize." Archiv fur Anatomie und Physiologie. 1880, p. 72.

Hugo Kronacker und G. Stanley Hall. Die willkurliche Muskelaction. Archiv für Anatomie und Physiologie, 1879.

[4] Dr. R. U. Limbeck, "Uber den Rhythmus centralie Reize." Archiv für experimentale Pathologie. Bd. XXV. H. 2.

The difference between the rates for cortex and cord is worthy of note in consequence of the close correspondence of the number of shocks for the cortex and the rate of the most rapid voluntary control; while involuntary and clonic contractions which find their seats in the lower centres and in the cord may be much faster. In this connection the attention of the reader is called to that portion of the experimental study in which the rate of clicks at which rhythmical grouping ceases is set forth. It is not far from ten a second. This is also near the lowest rate at which air vibrations give the impression of a musical tone.

The theory of summated stimuli which was advanced by Wundt, and which is generally accepted, is based upon the resistance which a central cell offers to a stimulus. The incoming stimulus is not communicated directly to the cell. The afferent nerve does not terminate in the cell, but breaks up into branches, which form a kind of envelope about the cell. The efferent nerve takes its rise in the nucleus of the cell and proceeds towards the periphery. If the stimulus is weak, it does not penetrate through the surface of the cell to the nucleus, but only part way. It sets up a kind of disturbance around the surface of the cell and, should another stimulus follow before the disturbance has subsided, it adds to the effect already produced. Repeated stimuli still further increase the disturbance until it penetrate to the nucleus of the cell, when it causes the cell to discharge into the efferent nerve. This serves very well for summated stimuli, but other phenomena of just the opposite nature require explanation. There are the soothing effects of slow and gentle stroking or patting, such as hypnotizers and nurses use upon their subjects. The general fact seems to be that the stimulus must not rise much above the threshold, and be sufficiently slow, that there shall be no summation. As we shall see later, any repeated stimulus tends to take the form of a muscular movement accompanying it. If this stimulus becomes gradually slower, it leads finally to the concept of rest, and being accompanied by muscular movements, these movements must finally cease. Increased quietude follows the slowly decreasing movements, until before a great interval of time has elapsed the body falls into a state of rest. The stimulus must in any case be sufficient to command the attention of the subject to the exclusion of the disturbing effects of other stimuli coming from without and from the involuntary processes of the body. Let us return now to the nerve cell, to find if there are any processes going on which will throw light upon the problem. A weak stimulus is continually playing upon the cell from without, but never rises sufficiently

in strength to penetrate beyond the periphery of the cell or in rapidity to bring about a summation. The effect of each stimulus subsides before the following one reaches the cell. The peripheral area must soon become fatigued so that it is no longer able to respond to the stimulus, and yet it is sufficiently strong to command the attention in so far as to distract it from other stimuli coming from within. This is the condition of quietude in the cell which is manifest in the muscle.

Attention and Periodicity:—The most casual observer will discover that his attention is discontinuous and intermittent. It manifests itself in a wave-like form. It is a series of pulses. The mind does not rest for any length of time upon a single object. New phases and relations must continually appear, or the object is dropped, that another may be taken up. "No one can possibly attend continuously to an object that does not change."[1] This process has been described as a "fly and perch." Charles Pierce says in his "Philosophy of Attention" that there is "no continuum." This periodicity in attention has been observed by Helmholtz[2] with the stereoscope and commented upon at considerable length. The phenomenon is called retinal rivalry. Mr. T. Reed[3] records some observations which he made in combining two stereoscopic views, which were ruled, the one with vertical, and the other with horizontal lines. He finds that the whole field will be occupied for a time with one view, and then this gives way for the other, which lasts an equal time. They seem to change without voluntary effort and even in spite of one's efforts to keep one view in the field. The full time for a change from one to the other and back again is from twelve to sixteen seconds for different subjects. The pulses of attention, however, seem to succeed one another at much shorter intervals. Two seconds seem a long time to hold any object which has no relation before the attention. James says: "There is no such thing as voluntary attention sustained for more than a few seconds at a time." Does it not, then, seem reasonable that during each wave or pulse of attention only one undivided state of consciousness can arise? The waxing and waning of attention seem to mark a change from one object of consciousness to another. The object of the state may be very complex, but it stands as a unit in consciousness. The problem of the relation of the parts of the object by which a great many may be allowed to stand as

[1] James, "Psychology," Vol. I. p. 420.
[2] "Physiologische Optik," Sec. 32.
[3] "Nature," August 1, 1887.

a unit in consciousness and be grasped in a single state, is of the most vital importance, but it must be deferred until later, when the normal period of a wave of attention will also be discussed.

Rhythmic Speech:—The most distinguishing, and in many respects the most important, function of the human body is vocal utterance and articulate speech. Being an involuntary and habitual function in a large measure, it might be expected upon *a priori* grounds to be rhythmical. Speech becomes rhythmical not simply by sounds succeeded by pauses, but also by the regular recurrence of strongly accented sounds in a series. Aside from the simplest shout or exclamation of joy or pain, all vocal utterances are primarily rhythmical. Every word that contains more than one syllable consists of strong and weak syllables. These accents occur upon every other syllable in varying intensity, or at most the accented syllables are separated by two unaccented syllables. As regards vocal utterances, they can be considered from four different aspects—their regular succession, intensity, pitch and quality. The problem in a philosophical treatment of rhythmic speech is to determine the value of these properties of sound as unifying elements in a rhythmical production. It will be necessary first to inquire which is the most fundamental, and secondly, where each enters and the part it plays in the development of literature. We must seek also other unifying principles, if such there be. Of these, we might now mention the logical meaning of words—the theme—and æsthetic forms. As we are concerned in speech in so far only as rhythmical effects are aimed at, we shall speak only of poetry. By what coördinations and subordinations of sounds with respect to their properties and meanings is the whole structure of the poem held together? It is the same problem which Plato discussed as the one and the many. Kant put the same question by asking how the mind made a unity out of a manifold. We have to ask how the mental span becomes so enormously increased as to grasp such a poem as Wordsworth's "Intimations of Immortality from the Recollections of Childhood," or Milton's "Paradise Lost." How is the carrying power of the mind increased to such an extent? The answer is to be found in the fact that unities are formed out of the simplest elements of speech by coördinating some with others in respect to their time relations; secondly, unities are formed of unities by subordinating them with respect to their intensities, and sometimes, their time values; thirdly, by coördinations and subordinations with respect to intensities and qualities, higher unities still are formed; and

fourthly, by coördinations and subordinations with respect to theme and æsthetic forms, the greatest unities are accomplished. In the first place vocal utterances are related as regards time, that is, the same sound may recur at regular intervals, in which case the series thus formed might be termed a *rhythmic* series—a series which may become rhythmical. In the next place this series might be made up of louder and weaker sounds alternating with each other. The series would then be composed of groups of sounds and might be called a *rhythmical* series. This is a rhythm in speech. If now the louder sounds in each group were given different intensities, these smaller groups might be brought into larger groups still. In this way the mental span may be made to extend itself over a very large number of simple impressions. The principle is very clear, and one will see at a glance that if intelligible sounds were used and qualitative changes employed, the mental span might be almost indefinitely extended. The carrying power of the mind, however, does not rest wholly in any case upon a single fact, if we make the exception that vocal utterances must be carefully timed in a rhythmic series. Quality and pitch changes accompany changes in intensity, so that the subordination of one sound to another and their consequent unification with respect to intensity is always dependent upon pitch and quality changes as well. For this reason it is impossible to treat each properly by itself.

Time-relations:—In order for vocal utterances to form a rhythmic series, they must occur at regular intervals of time which cannot exceed or fall much below certain limits. We may, however, upon the analogy of physiological rhythms, regard a series of sounds recurring at stated intervals as a rhythmical series, and also regard the recurrence of accented sounds as forming a secondary rhythm out of the primary. This is carrying the rhythmical idea farther than has been customary, and while it is more nearly correct, it would not be generally understood. The question of the time values of vocal utterances for rhythmical purposes cannot be answered upon an examination of poetry itself. Although the Greeks and Romans assigned exact values to all syllables in their language, there is reason for believing that such values did not arise naturally, but were assigned when they began to speculate upon poetry. No such relations exist among the syllables of modern languages, and in English they never did. We must then dismiss the subject of time and its significance and revert to it as the subject permits.

Intensity of Sounds:—The mind accomplishes its first real unification of sounds by subordinating them with respect to their intensities. A rhythm in speech means a series of groups of sounds. Each group may contain two or more sounds, generally not more than four. Two sounds, one strong and one weak, the one succeeding the other in time, cannot give an idea of a rhythm, but two groups of two such sounds certainly can. This being the simplest possible rhythm, we should expect that it would be the earliest form in which literature appeared. Since we have not probably any extant specimens of the first literary productions, for they were not committed to writing, we must judge from those which have come down to us from later periods, and from the literature of primitive peoples and of children, what the earliest form was. In this way it has been proved that our surmise, which was made upon *a priori* ground simply, is correct. The oldest extant specimens of English poetry are generally composed of verses of two sections, which are separated by a pause in the middle. Each section generally contains four, sometimes six, syllables, two of which are unaccented and two accented. The first section was emphatic and corresponded to the accented syllable in the smaller division; the second section received less stress and was less important. The two formed a kind of balance structure, in which the first section contained a rise and the second a fall.

helle heafas: hearde nithas.
wer leas werod: waldend sende.
graes ungrande: gar secg theahte.[1]

"Our Anglo-Saxon[2] poems consist of certain versicles, or, as we have hitherto termed them, sections, bound together in pairs by the laws of alliteration. . . . . For the most part these sections contain two or three accents, but some are found containing four, or even five. The greater number of these sections may be divided into two parts, which generally fulfill all the conditions of an alliterative couplet. . . . ." These are the rules that Guest gives according to which the elementary sections were constructed: 1. "Each couplet of adjacent accents must be separated by one or two syllables which are unaccented, but not by more than two." 2. "No section can have more than three or less than two accents." 3. "No section can begin or end with more than two unaccented syllables." "When the accents of a section are separated

[1] These lines are copied just as they appear in Guest's "History of English Rhythms," p. 189.
[2] Guest's "History of English Rhythms," p. 158.

by two unaccented syllables, the rhythm has been called triple measure; and the common measure, when they are only separated by a single syllable." The greater proportional number of accents makes the movement slower, and adapts the measure for more solemn and graver subjects. The triple measure is more suited to lighter themes. The verse of the common measure is made more energetic by being begun and closed with accented syllables. They are abrupt when too short, and become feeble when too long. There was considerable variety of rhythm as early as the fifth century, "as there certainly was in the seventh century, when Cædmon wrote."[1] "It is, however, probable that the rhythms were of a simpler and of a more uniform character." .... "Most of the alliterative couplets have only four accents—very few, indeed, have so many as six."

The phenomenon of accompanying the changes of intensity in a series of sounds with muscular contractions, led to the early association of dancing with musical and poetical recitation. Indeed, if we accept the current theory of the origin of language as arising during the celebrations of victory, dancing precedes even language. Just as an animal jumps and frisks about as an expression of pleasure at seeing his master, so our ancestors danced for joy over a victory, or in the worship of their deity. They emitted certain vocal utterances in company with the tramping of the feet, which in time came to have definite meanings and also took on the rhythm of the dance. This rhythm was scarcely more than the simple swaying of the body or the lifting of one foot and now the other. Variations in the dance might occur either in taking several steps forward and then several backward, or to the right and to the left. These variations would produce corresponding effects in the vocal accompaniment. The step of one foot would be stronger and a more intense sound made to correspond to it. In the same way either the forward or backward movement would become the more important and give rise to the distinction of thesis and arsis of the verse. Further groupings of the verses might take place in the same way. The two-rhythm was apparently the prevailing rhythm in the history of our language, if not in some others. The most common foot in our literature of all times, and a very common foot in the Greek literature, consisted of two syllables; two feet entered into the section, and two sections formed an alliterated couplet or verse. It is the simplest possible rhythm, and corresponds to the leg-pendulum with which the language was so intimately associated in its earlier history.

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[1] Guest's "History of English Rhythms," p. 169.

Noiré[1] believes that language took its rise in the concerted action of many persons. In this way the individual finds that what belongs to him is the common character of others. Such utterances as "hi-ho" are taken to be the first beginnings of language, and they originate during concerted action. Any sound that is to become intelligible must first be experienced in company and then by the individual alone. But, as the example shows, such utterances are rhythmical. Here it is the rhythm of heaving sails or anchor, which is seen among sailors.

Variations in the number of syllables to the accent would be a necessity as a relief from the monotony of two syllables to the accent, and so, too, the number of accents to the section would be increased on account of the abruptness of the doubly accented section. Taine[2] in speaking of early Saxon poets says: "His chief care is to abridge, to imprison thought in a kind of mutilated cry." "They (Saxons) do not speak, they sing or rather shout. Each little verse is an acclamation which breaks forth like a growl. Their strong breasts heave with a groan of anger or of enthusiasm. A vehement or indistinct phrase or expression rises suddenly, almost in spite of them, to their lips." After the people became settled down in their new homes, they lost the ruder and rougher characteristics, and such wild outpourings would be no longer suited to their milder spirits. The changes that took place in the development of our literature are due in some measure to the change in the life and habits of the people.

There still remain in our poetical compositions certain evidences of some, at least, of the stages through which our poetry has passed. The choruses in many of our hymns are still made up of non-sense syllables. Irish melodies and popular songs retain this feature. Children's poetry — by that I refer to such poetry as they enjoy and recite for their own amusement — has a large element of purely unmeaning sounds in it. Savage dances are often accompanied by recitations in which no meaning has been discovered. Again, savages and children are frequently found repeating for their own amusement a series of non-sense syllables in rhythmical form. The accents are very strongly marked, and frequently enforced by alliteration. The incoherent chatter of a maniac, or the sound of a foreigner speaking his language to one who is unacquainted with the language, is distinctly rhythmical. It is more like a chant, and children frequently remark upon

[1] Ludwig Noiré, "Max Müller and the Philosophy of Language."
[2] Taine, "Introduction to the History of English Language."

it. It appears, then, that vocal utterances which are kept up for a considerable time fall into a rhythmical form. Such being the natural tendency of speech, it would conform itself to any rhythm with which it might be associated, and as vocal utterances were always accompanied by the dance, it would take on the rhythm of the dance, which in its earliest forms we have seen reason to believe was the leg-pendulum.

The poetry of children shows a character very similar to early English poetry. It consists often of a two-section verse which is strongly alliterated, and in which the rhythm is perfectly clear. The familiar incantation rhyme shows this characteristic very well.

> Sticks and stones
> May break my bones,
> But names will never hurt me.

Again,

> Jack and Jill
> Went up the hill
> To fetch a pail of water;
> Jack fell down
> And broke his crown
> And Jill came tumbling after.

At the beginning of each couplet there is wanting one syllable. Their poetry is usually accompanied by marching or by clapping of the hands, so that they require an accented syllable at the beginning. The verse is, then, an alternation of accented and unaccented syllables; occasionally only two unaccented syllables occur between two accents. We have in the first couplet what was found to be a prominent characteristic of early English poetry.

E. B. Taylor in his "Anthropology" asserts that while meter, and by that he means lines regularly measured in syllables, is an evidence of civilization, one of its earliest developments is matched and balanced sounds. The Australian savage sings at the end of his verse, "A bang! A bang!" Certain of the North American Indians sing in choruses, "Nyah eh wa! Nyah eh wa!" The chorus of a New Zealand song is "Ha-ah, ha-ah, ha-ah, ha!" A feature extremely common in barbaric song is a refrain of generally meaningless syllables. Guest,[1] speaking of our early poetry, says, "I have hazarded the opinion that these short, abrupt and forcible rhythms were the earliest that were known to our language. They are such as would naturally be prompted by excited feeling, and well fitted for those lyrical outpourings which form the earliest poetry of all languages." The abruptness

[1]Guest's "History of English Rhythms," p. 365.

is felt by children, so that not more than a single couplet appears without the intervention of a different kind of verse. Shakespeare[1] adopted this measure in his descriptions of fairyland, and it is now become the fairy dialect of the English language.

Qualities of Sounds: — Qualities of sounds are quite as important as unifying elements as their time and intensity relations, and were quite as early regarded. This is manifest from the frequent recurrence of the same sound at the beginning of Anglo-Saxon and Germanic verses. This is alliteration. The two sections of the verse, while contrasted in intensity, were coördinated by the recurrence of the same sound. The origin of alliteration is involved in some mystery, and yet the savage shouts just quoted point out a possible origin. The emotional shout of an animal for a given state is always the same; but for the savage, who possesses greater powers of utterance, emotions find various expressions, or at least, if the expression begins with the same sound, it ends differently. Although the New Zealand savage shouts "Ha-ah" several times in succession, he closes with "Ha!" When the child torments his companion in the midst of misfortune, he says "Goody, goody gout." Other expressions of a similar character, but used with a different purpose, are "higelty, pigelty," "hee-ho," etc. In modern poetry alliteration has given place in a very large measure to final rhyme, which has become the unifying factor for the verse generally in English poetry and always in French. The qualities of sounds gave rise to melody in speech, which is common to both poetry and music, and it is as melody that the qualities of sounds play the most important part.

Spencer holds, in his essay upon the origin of music, that different emotional states produce different intonations and changes in pitch, quality and loudness of vocal utterances. In the savage dances of victory, worship, and love, emotional speech grew up, and from this music arose. Originally music was recitative—a mere chant. Chinese and Hindoo music is still so. This recitative speaking grew "naturally out of the modulations and cadences of strong feeling." The Quaker preacher who speaks only when moved by religious emotion, speaks with a recitative intonation, and church services of the present day are generally read so. This is really melody. Recitative speaking, or emotional speech, constitutes the whole of savage poetry.

Poetry and music among primitive peoples were the same. Poetry was either sung or chanted, and it was not until a

[1] Guest's "History of English Rhythms," p. 179.

later period that they became separated. With the discovery of the musical instrument, the people saw that a melody was just as well expressed by simple tones as by intelligible syllables, and music took up its own lines of development.

The Emotional Effects of Rhythm upon Savages and Children:—There is no more striking fact in the whole field of rhythm than the emotional effect which rhythms produce upon certain classes of people, savages and children. Attention has already been called to the psychological phenomenon of accompanying the changes of intensity in a series of sounds by muscular movements. So strong is this impulse in all classes of people that no one is able to listen to music in which the rhythm is strong and clear without making some kind of muscular movements. With some people these movements tend to increase in force until the whole body becomes involved and moves with the rhythm. The accents in the rhythm have the effect of summated stimuli, and the excitement may increase even to a state of ecstasy and catalepsy. Although the regular recurrence of the accented syllable is the most important element, the qualitative changes aid in bringing about the emotional states. Soothing effects result from certain rhythms, as is shown in the lulling and patting of the baby to sleep. The early hypnotizers resorted to the gentle stroking of their subjects. Savages are well aware of the exciting effects of certain rhythms, and are accustomed to use them to bring about the state of frenzy in which their priests give their prophecies and in which religious dances are danced. Mr. Ellis,[1] who has made a study of some tribes in Africa, says, "Music amongst the Thsi-speaking tribes is limited to airs possessing an obvious rhythm. Such airs seem to appeal to the primitive sense common to all people, but upon savages, that is, upon children with the possession and power of men, its influence is immense, and the state of excitement into which an assemblage of uncivilized people may be wrought by the mere rhythm of drums and the repetition of a simple melody would hardly be credited. . . . . With some races this known emotional influence of music has been utilized with three objects, viz., to stimulate the religious sentiments, the martial spirit, and the sexual passions."

In the Yatiati[2] dance among the Indians of British Columbia, the tribe assembles outside of the chief's house in which the dance is to be held, and with fists and sticks they beat the time on the walls as they enter, singing the dancing

[1] A. B. Ellis, "The Thsi-Speaking Peoples of the Gold Coast of West Africa," p. 325.

[2] Franz Boas, *Jour. of Amer. Folk-lore*, Vol. I. p. 49.

song. The dancers who are on the inside are worked up into a frenzy. The gentle striking at first, gradually increasing in violence, and the slow approach and the assemblage of the tribe, wrought in the dancers a pitch of excitement which forced them to rush out after a time and begin the dance, jumping about in the wildest fashion. Such dances cease only with the complete exhaustion of the dancers.

The Patagonian wizard[1] begins his performance with drumming and rattling, and keeps it up till the real or pretended epileptic fit comes on by a demon entering him. Among the wild Veddas of Ceylon the devil dancers have to work themselves into paroxysms to gain the inspiration whereby they profess to cure their patients. With the furious dancing to music and the chanting of attendants, the Bodo priests bring on a fit of maniacal possession. The excitement is allowed to continue until the prophet falls to the ground in a swoon. When the Alfurus of the Celebes invite their deity to descend among them, the priests, standing about the chief priest, upon whom the deity is to descend, chant some legends. A slight twitching of the limbs marks the beginning of the possession. The priest turns his face towards heaven, the spirit descends upon him, and with terrible gestures he springs upon a board and beats about with a bundle of leaves, and leaps and dances, chanting some legends. He falls in a swoon, and the sounds he emits are interpreted as the will of the spirit.

George Catlin[2] says dancing is always accompanied by the singing of mysterious songs and chants, which are perfectly measured and sung in exact time to the beat of the drum, always with an invariable set of sounds and expressions.

The religious services and singing among the Shakers are often accompanied by dancing, and more frequently by beating of the time by all the members of the congregation. The excitement among them never rises to an extreme degree. A highly civilized people is not easily affected by mere rhythms. A simple tone is not so expressive as it is to the lower classes of people. The negro preacher often resorts to recitative speaking to produce the desired emotional state in his hearers, which is generally known as the "power." He selects some short sentence, often unimportant, such as "Moses went up into the mountain," and repeating this, at first softly, he gradually raises his voice to the highest pitch, at the same time increasing his gesticulations. The more excitable of his audience are thrown into a paroxysm ; the con-

[1] E. B. Taylor, "Primitive Culture."
[2] George Catlin, "Letters and Notes upon the Manners and Customs of North American Indians."

tagion spreads so that sometimes the whole audience is involved. Evangelists among all classes of people rely more or less upon the emotional effect of rhythmical speaking. Street hawkers and fakirs generally speak with a recitative intonation. Their success depends very largely upon their success in alluring and holding the attention of the crowd by the manner and intonation with which they speak.

The effect of rhythm and clearly accented music is no greater upon primitive peoples than upon children. Although children are not allowed to go into ecstasies, the clapping of the hands to the recitation of "Peas porridge hot" is akin to the terrible leaping and gesticulations of the savage to the accompanying tom-tom and the chanting of his ancient legends. The child usually begins his recitation of "Peas porridge hot" rather slowly, and as he continues he grows in excitement and enthusiasm, his gestures become more violent and rapid, until he breaks down in the excitement. It is a well-known fact among school teachers that young children become excited whenever they sing rhymes with a strongly accented rhythm. Several have made this observation during the singing of a certain line in Theodore Tilton's "Baby Bye." The line in which the excitement reaches its climax is,

> There he goes
> On his toes
> Tickling baby's nose.

This is a type of the fairy measure. The accents are strong, and every line is preceded by a pause, and at the same time all the lines are rhymed. Both the rhyme and the pause lend an intensification to the rhythm that is sufficient to call out the greatest excitement in the fairy people. In Robert Browning's poem of the "Pied Piper of Hamlin," whose charm was rhythm, occurs this remarkably rhythmical passage, and taken with the context might easily cause some emotional excitement:

> Into the streets the piper stept,
> Smiling at first a little smile,
> As if he knew what magic slept
> In his quiet pipe the while.

I have the testimony of an eminent educator that, when he read these lines, and he is an effective reader, his boy, a youngster of five or six years, would run away and hide where he could not hear the reading. He was apparently unable to bear the strain of the excitement. In later years the boy could not tell why he did so, except that it disturbed him.

The use by children of incantation rhymes for purposes of injury and torment to their companions is interesting in this connection. The habit of rhyming is almost instinctive with them. Imagine the effect of such a couplet as this upon the child to whom it is addressed:

Good night,
Rosie Wright.

Again, any name may be put in certain adaptive rhymes which are current among children. These, however, are not so effective as the instance cited above. They admit of retort. The drawling out of a name in a sing-song measured tone is very effective, and the easy adaptation of some names makes the child who is unfortunate in having such a name an object of torment.

The Place of Rhythm in Music and Poetry. Music:—We have seen how music and poetry took their rise together from the emotional utterances of savages during the dance, and how these emotional utterances gradually took the form of recitative speaking. This gave rise to the melody, though it was not disassociated from the meaning of the words. With the discovery of the musical instrument came the discovery that a melody might be sustained by simple tone intensities. Although music finds its essential basis in rhythm, its distinctive feature is the melody combined with harmony. The melody is constituted of a succession of tones which are significant of an emotional state, and when several melodies are combined and sung together, they give rise to harmony. This combination of melodies depends upon the pitch of the sounds. The melodies in harmony are all subordinated in different degrees to one dominant melody which is higher in pitch than the others. The unifying element here is pitch. This is the only distinctive use that is made of it in either music or poetry. The most important and fundamental unifying principles underlying music is the time, without which there can be no music. Musical tones must be exactly timed, if one is to get the conception of a melody from a series of tones. When they are exactly timed they may be farther unified by regular changes of intensity which group the sounds into measures. The most common measures that occur in music are 2-4, 3-4, 4-4, and 6-8 time. In what might be termed the natural system of accents, the first note in each measure receives a strong accent. This is really the only accent in 2-4 time. In 3-4 time the second note also receives an accent, but it is weaker than the first. In 4-4 time there are four grades of intensity. The first note is the strongest, the third next, the second is weaker still,

and the fourth is the weakest of all. In 6-8 time the third, fifth and sixth are of about equal intensity, and weak. The first is strongest, the fourth is next, and the second weaker though stronger than the third. An equal amount of time is given to each measure—that is, the strong accent occurs at regular intervals—but the distribution of this time among the notes in a measure may be greatly varied; the separate notes, however, always bearing constant and simple relations to one another. The smallest fraction that may express the relations of these notes is 1-64, and this appears only in instrumental music. In poetry, as we shall see, there is not so much freedom; it has deviated less from the primal rhythmic stock from which both spring. For many centuries music consisted wholly of melodies, or of a single melody. The idea of combining or singing several melodies at the same time came very much later. This is harmony. It reached its highest development about Elizabeth's time, when the attempt was made to combine as many as forty melodies. A much smaller number was found to give better effect, and the number now used is generally only four. Symphony was a still later development, but the general feeling among musicians now is that it culminated in Beethoven, and its further development in music is impossible. Although the term has had several significations in the history of music, in Beethoven it was the combination of several themes in such a way as to bring about a succession and combination of strong emotional states. The musician who desires now to produce new effects, turns to the Volks-Lieder for a theme. He aims at variations of the rhythmical effects and introduces new harmonies. Mendelssohn is said to have remarked, when he heard some of the negro melodies of our slaves, that here was a field for a great musical talent. Wagner, taking the suggestion, has made such an adaptation of the Hungarian melodies, and with what success the musical world is well aware. Wagner has made a real advance, and for some time musical composition will follow his lead. Although there is a feeling among musicians that rhythm is distasteful, it is more apparent than real. It is the regular monotonous recurrence of the same rhythm without sufficient variations that is displeasing and not the rhythmic flow itself.

Rhythms in Poetry:—We have already seen that when language appeared as literature, it took the form of the simplest possible rhythm. Even then it was the vocal accompaniment of a dance, and there are many analogies to the simple swaying of the body or the tramping of the feet in the march. There were no fixed rules in regard to the number of syllables to the measure. The verse, so far as we can

speak of a verse, consisted of an alternation of accented and unaccented syllables. Very generally it began and ended with an accented syllable, so that a pause occurred between each verse. The line of development along which poetry followed was an increase in the number of unaccented syllables as compared with the accented, and also an increase in the number of accents to the verse; the verse preserving for some time the same balance of structure that it had in the beginning. The number of accents then might be four, six or eight; the latter number never became popular, for the reason, it would seem, that it exceeded the normal mental span. This even and balanced structure could not hold out forever; a demand for variety and the influence of foreign rhythms contributed to overthrow it, so that Chaucer wrote altogether in a verse of five accents, but he still retained the middle pause. This came after the second accent or just before the third, though sometimes after the third also. There were many verses in which the first section more generally contained three accents.

Guest takes no account of the measures or feet in English verse. He divides lines into three general classes: Those that begin with an accented syllable, those that begin with one unaccented syllable, and those that begin with two unaccented syllables. The varieties in each of these classes depend upon the position where the variation occurs from the form in which the verse sets out. Should the verse begin with an accented syllable and continue with an alternation of accented and unaccented syllables, it would constitute one variety. If, however, two unaccented syllables occur between any two accents, it would constitute a different variety according as the two unaccented syllables occur between the first and second accents, the second and third, and so on through the verse. Early poetry was sung to the accompaniment of the harp and hence was sung in exact time. On this account Guest says that up to the fourth century, English rhythms were temporal and then became accentual. Previous to that time the syllable had a time value. This, however, is not to be taken in any absolute sense. Poetry was chanted in a kind of trance state, and the reciter aimed to produce such a state in his audience. For this purpose the thought was of minor importance. Great dependence was placed upon the rhythmical flow, and doubtless a very exact time was given to the syllables that the movement might be clearer. A rhythm which depends wholly upon either the time element or the accent, is certainly less forcible than one which combines both factors. It must be conceded that though some regard was paid to the time of syllables, no such exact time was main-

tained as modern musicians keep in their music. Perfect time is the result of the application of scientific methods to music. Poetry has never lost the time element entirely, for accents that occur at irregular intervals could not have been but very displeasing, and they are now. It is reported of some of our modern poets, and especially of Tennyson, that they read their poems with the strictest observance, not only of the accents, but of the time, showing that they regarded the time element of great importance. Many readers and teachers of English poetry pay little heed to the regular recurrence of the accent. For them the thought is the chief element in poetry, and in attempting to bring that out, they disregard the rhythmical flow. But when the proper observance of the thought does violence to the rhythm, the poet must be adjudged lacking poetic inspiration, and to that extent his poetry is not true poetry. It is to the great renown of Chaucer, Milton and Shakespeare that there is such a perfect adaptation of the rhythm to the theme in hand, and any lack of observance of the accents by the reader betrays his want of understanding of that which he reads. The strict observance of time in music and the unity of origin of poetry and music, which argues that time was once an essential element of poetry, show that the time element is still there, unless it can be shown when and why it has dropped out. Poetry has admitted fewer variations and allows a greater prominence to the rhythmical flow than music. It must be admitted, however, that the thought has taken the place of the melody to a great extent as the unifying element, but it cannot be allowed to take the place of other factors. Whenever it does, just so soon the composition fails of being in any sense poetry.

Alliteration, which was very prominent in Anglo-Saxon, was gradually lost. The influence of the church and of Latin scholarship aided somewhat in this movement, but as the Anglo-Saxon element prevailed against all foreign influences in the political and social affairs, it won the day in the struggle against the Norman and Latin languages. Our language remains essentially Anglo-Saxon, and alliteration, though less common, is still a prominent feature of our poetry. Originally, alliterated syllables marked the beginning of the section and constituted the unifying factor of it, but there was no strict observance of such a principle, except that the alliterated syllables were accented. They might come anywhere within the section. The use of alliteration by later English poets was to place the alliterated syllables away from the beginning of the section and to put them in the same verse. The purpose of alliteration is not to coördinate two sections or two lines, but, by intensifying certain accents in the verse,

to make a more perfect subordination of them, or to make a more perfect unity of the line. Final rhyme succeeded alliteration. The chief reason seems to have been for a more emphatic or distinguishing mark of the rhythm than could be obtained through accents alone; especially when run-on lines came to be used and the thought was about to usurp everything. When two successive sentences or words begin with the same sound, it interferes with the understanding of them. Both the reader and hearer are more likely to confound them. For this reason alliteration must give way, except for purposes of emphasis, when the thought becomes of the first importance. Simple intensities are not sufficient as unifying factors; they cannot be properly subordinated to give unity to the line. It is interesting to note how the change from alliteration to rhythm has come about. In the early poetry, the alliterated syllables came at the beginning of the verse, but in modern poetry the rhymed syllables, which are their successors, come at the end. We shall see later how the beginning and end of rhythmical groups run into one another and become indistinguishable. The same is to be observed with reference to the feet. The accents in the feet become transposed. Although it seems probable that the foot in early poetry and the measure in all music began with the accented sound, the accented syllable in English poetry is more generally the last, and in Latin and Greek poetry it was quite as frequently the last as the first. The series of accented syllables in the verse and of articulate sounds in the foot seem to appear as a series of stimuli which are to be summated.

The two sections of the verse in old English were made to rhyme with their last syllables, and were then written as two verses. Two such couplets together form the most common stanza in English poetry. Instead of writing the members of each couplet next to each other, they are made more frequently and quite generally to alternate.

Æsthetic Forms:—That which binds the four verses into a stanza is not wholly the interelation and balance of the two rhyming couplets. The members of the two couplets are frequently made to begin, the one with an accented syllable and the other with an unaccented syllable. Sometimes this, and sometimes a less number of accented syllables, make the lengths of the alternate lines less—a fact that gives artistic form to the verse when it is properly printed. It becomes then an appeal to the eye as an æsthetically beautiful form. This principle was seized upon by our poets during the sixteenth century, and carried to an extreme as regards form alone, which could not be sustained by the thought. The

poem had nothing but form. The principle of form becoming a unifying factor for a poem is perfectly true, and effective use is made of it in modern poetry. Among the older poets, George Herbert introduced many novelties into the forms of stanza. He relied upon both rhymes and artistic forms. Some of his stanzas take the form of a vase, an hour-glass, a pyramid and an inverted cone. Although they read smoothly, one cannot help but feel that his attempt at æsthetic forms has destroyed the beauty of the poems.

The sonnet[1] is probably the most organic of all poems. While the theme is very essential in binding the whole together, the lines are coördinated in the most intricate way by rhymes. A rhyme-scheme runs through the whole, which, when represented by letters, or dots of different sizes, or lines of different lengths, forms an artistic group, obeying the laws of principality, subordination, etc. The number of accents to the line is varied in some cases in such a way that it lends a kind of subordination of some lines to others, or of all to one or two.

Theme:—Little or no regard is paid to the thought in a poetical recitation by children or by primitive peoples. They delight in the emotional effect of sounds properly measured and balanced. With the growth of literature the thought has gradually become more important until it is about to usurp everything. The unity of the stanza and of the verse very generally depends upon it. Higher unities of the stanza—poems—depend entirely upon the theme. The attempts to coördinate stanzas by rhyming their last lines have not proved a great success. The strength of the connection is often lost. If the thought in the verse or stanza is allowed to become the prevailing element, the poetry becomes measured prose. Poetry arose in a kind of trance or highly emotional state, and for centuries it was used to produce such states in others. The whole structure is calculated to produce emotion, and for that reason it cannot easily become the medium of expression for the intellect. There must be a mutual dependence between the thought and the form, or they result in mutual destruction.

Under the influence of the church and Latin scholarship, English poetry became, or at least the attempt was made to conform it to certain rules of Latin prosody. English critics, misunderstanding probably both English and Latin poetry, tried to make the former conform to the rules of the latter. And there are many persons now who cannot see

[1] The reader is referred to Prof. Corson's "Primer of English Verse" for a treatment of the stanza and sonnet.

why the rules of Latin prosody are not universal. A verse beginning with an accented syllable and consisting of an alternation of accented and unaccented syllables, was trochaic measure, and the accented syllable was double the length of the unaccented. If two unaccented syllables were used between two accents, it was the substitution of a dactyl for a trochee. In this case, if the syllables preserved their proper time values according to the Latin prosody, four time-units—the dactyl—would appear in the place of three—the trochee. This, however, did not strike the critics as forming a defect in the rhythm, and the error has gone on. It is the current view among respectable English authorities to-day. In order not to keep the reader in suspense about so disputed and important a point, let me say what seems to be the true view. As the simplest time-unit of Greek poetry was a short syllable, and whatever value in time was given to it in a verse, that value must be maintained throughout, so the simplest unit of English poetry is the time between two accents—the foot is the simplest unit in the verse—and this must be constant. The time is apportioned among the syllables that are present between the accents, whatever the number. From the very nature of the accent the syllable receiving it will be longer relatively, though it does not bear a constant and simple relation to the length of the unaccented syllables. "Besides the increase[1] of loudness and the sharper tone which distinguishes the accented syllable, there is also a tendency to dwell upon it, or, in other words, to lengthen the quantity. We cannot increase the loudness or the sharpness of the tone without a certain degree of muscular action; and to put muscular action into motion requires time."

Another fact which has been greatly overlooked in the study of English rhythms, and which has led to much confusion and erroneous speculation and criticism of some poets, is the sectional pause, which allows two accented syllables to stand together in the verse. It was very common in Anglo-Saxon poetry, and disappeared almost entirely under the influences spoken of above. Shakespeare made free use of it, and for a lack of this knowledge, critics assert that he made use of false accents. Cædmon placed it before words upon which he desired to have a strong emphasis. It occurs before names of the deity. Guest says it owes its existence to the "emphatic stop," and is really the greatest departure from the rules of accent, which were observed with much care by the Saxon poets. It has been revived by more

[1] Guest's "History of English Rhythm," p. 75.

recent poets, and effective use is made of it. The value of this pause is the great emphasis it lends to the word following, and my purpose in dwelling upon it now is that it will come up again prominently in the experimental study.

Another question which connects itself very closely with this point of accent and pauses, is the foot or measure division of the line. Guest does not recognize such a division as the foot. The line is an alternation of accented and unaccented syllables, and he does not mention the fact of these forming groups which in Greek prosody were called feet and in music are termed measures. There seems to be no question that readers do make such groups by placing a slight pause either after or before the accented syllables. The Greeks associated these groups with a complete step in the march, and since in matters of æsthetics it is a rash thing to dispute or deny the accuracy of their judgments, we must regard the foot as a real division of their verse and inquire whether the lack of quantity in English syllables has anything to do with the absence of the foot division. The English verse is made up of a series of syllables in which every other one is uttered with greater intensity than the rest. The accented syllable requires more time, and the unaccented syllable unites or fuses with it into an organic group. These groups are then apparently separated by pauses. In French poetry there are no accented syllables, and the foot division is not recognized at all. This gives English poetry a kind of intermediate position between Greek and French poetry. The question of a foot division cannot be finally answered from an examination of our poetry, except as has already been said, such divisions are invariably made. The question will find its final answer in the experimental investigation.

Another problem which follows closely upon this is, what is the inherent nature of a group in a rhythmical series, or, what is the relation of the different syllables to one another in the poetical foot, and what determines the length of it?

The length of sentence[1] in prose is found not to deviate long from an average. Long sentences may prevail in an author for a few pages, but they are sure to be followed by short ones in sufficient number to balance the long ones. There appears a kind of rhythm in which long and short sentences succeed one another. This rhythm is constant for the same author; his earlier and later writings show no difference in the length of sentences. The writers of the more ancient prose show a greater average length of sentence than our more recent writers.

[1] L. A. Schurmann. University Studies, Nebraska University, Vol. I.

There have been several attempts in late years to construct philosophies of English verse. Several of these will be taken up and their more salient features presented. The purpose is not to give a complete review of the books, but to call attention to a few facts which will supplement the work that has gone before.

The Science of English Verse by Sidney Lanier:—A simple auditory impression recurring at regular intervals of time furnishes the essential conditions of a rhythm. Of the four properties of sounds—duration, intensity, pitch, and tone-color—the mind can and does form exact coördinations of duration, pitch, and tone-color; intensities cannot be compared with exactness. The regular recurrence of sounds and silences constitutes primary rhythm, and a grouping of these sounds by means of intensity, pitch, or tone-color, constitutes secondary rhythm—the bar in music and the foot in poetry. For purposes of verse, syllables correspond to sounds and bear relations to one another in point of time, which are expressed by the simple numbers 1, 2, 3, 4, etc. The regularly recurring syllables of a sentence, whether prose or poetry, constitute a primary rhythm, "which the rhythmic sense of man tends to mould into a more definite, more strongly marked and more complex form, that may be called secondary rhythm." "The tendency to arrange any primary units of rhythm into groups, or secondary units of rhythm, is so strong in ordinary persons that the imagination will even affect such a grouping when the sounds themselves do not present means for doing it." Accent simply arranges the "materials already rhythmical through some temporal recurrence." As the comprehension of a series of sounds is rendered more easy by grouping, so the comprehension of a series of these groups is rendered more easy by again grouping these groups into tertiary rhythms. Alliteration, the recurrence of emphatic words and punctuation marks signify the tertiary group. The fourth order of rhythmical grouping is the line which, except in the case of run-on lines, completes a logical division of the sentence. Lines are again grouped into couplets by tone-color coördinations. The fifth order of rhythmical grouping is the stanza, and a complete poem is spoken of as the sixth order.

The effort of the author, in his treatment of the foot, is to make the rhythmical accent and grouping correspond to the logical accent and meaning. For this purpose he treats at length the iambic foot, it being the most common in English poetry. Making use of musical terms, this foot is equivalent to three eighth notes, and its typic form is one eighth note

followed by a quarter note. Instead of the eighth note, the foot may contain two sixteenth notes, and instead of a quarter note, there may be two eighth notes, or a dotted eighth and a sixteenth. The foot may also contain three syllables, each being equivalent to one eighth note, or four syllables, but the four must be read in the time of three eighth notes. In the place of any note, may be substituted a rest of equal length. An anapæst or dactyl cannot take the place of ar iambic or trochaic foot, since the former are equivalent to fou time-units and the latter to three. He says there are two kinds of rhythm only—3-rhythm and 4-rhythm. All other kinds resolve themselves into these two; 2-rhythm is really 4-rhythm, and 5-rhythm is equivalent to a 3-rhythm and a 2-rhythm combined.

A Primer of English Verse by Hiram Corson: — The object of verse to him is "the expression of impassioned and spiritualized thought." It originates in "the unifying activity of feeling and emotion." Upon whatever objects "feeling[1] or emotion is projected, or with what it is incorporated—it is unifying." "The insulated intellect, in its action, tends in an opposite direction—that is, in an analytic direction. When feeling is embodied in speech, that speech is worked up . . . . into unities of various kinds." The primal unity is the foot, which is combined "in a still higher unity which is called the verse, and this in turn is combined into a still higher unity, which is called the stanza." "Rhythm is a succession and involution of unities, that is, unities within unities." It applies to a succession of either feet, verses or stanzas. Each class of unities has its combining principles; that of the foot is accent. Melody is the combining principle for the syllables. Alliteration is a common and effective form of consonantal melody. The combining agencies of the stanza are harmony and rhyme. Individual verses may be melodious, but when several are taken together they lack harmony. Rhyme is also an enforcing agency of the individual verse, and the emphasis resulting is neutralized in proportion as the verses are separated. Blank verse depends "upon the melodious movement of the individual verses, pause melody, and the general harmony or toning." Variations of the theme-meter produce important effects. "The feelings of the reader of English poetry get to be set, so to speak, to the pentameter measure, as in that measure the

[1] This is the author's great mistake. No such distinction can be drawn between feeling as unifying and intellect as analytic. Both analysis and synthesis are equally properties of the intellect, and it is difficult to conceive how the feelings can accomplish a synthesis or unify anything.

largest portion of English poetry is written." The introduction of any other than the theme-meter gives an emphasis to the thought. The substitution of a different foot gives a variety "which is essential to harmony." The shifting of the regular accent gives a special enforcement, either logical or æsthetic. "There should never be a non-significant departure from a pure monotony."

Rationale of English Verse by E. A. Poe:—Verse originates with the human enjoyment of equality. Unpracticed ears appreciate simple equalities. Practiced ears appreciate equalities among equalities; they are able to compare two sets of equals. The rudiments of all verse may possibly be found in the spondee. In this, the mind finds its first pleasure in the equality of two accented syllables. A collection of two spondees—two words of two equal syllables—forms the second step in the development of the verse. A third step would be found in the juxtaposition of three words. This, however, gives the idea of a monotone, a relief from which is found in words of different accents—iambics. A dactyl might be employed as a further relief from the monotone. A sequence of words of any sort would form a monotone, if they were not curtailed or defined within certain limits. This gave rise to the lines, the terminations of which are again determined by equalities in length, and marked by equalities—likenesses in sound. Every foot in the same verse requires equal time. A three syllable word may appear as iambic or trochee, providing that two syllables can be read in the time of one. Blending is an unwarranted liberty. He states this general principle: The substitution of a foot, the sum of whose syllabic times is equal to the sum of the syllabic times of the foot substituted, is allowed with this restriction only, that the regular foot shall continue long enough or be sufficiently prominent to leave no doubt of the kind of verse. He says "that rhythm is erroneous, which any ordinary reader can, without design, read improperly." The real test of the perfection of a verse is the pleasurable feeling it yields.

Classical Poetry:—Classical Greek poetry was either chanted or sung, and for that reason was exactly timed. There was really no difference between a poetical recitation and a song. The simplest elements in the measure, according to which poetry was sung, was a time-unit equivalent to one eighth note. By combining these time-units into groups, they formed the measure or foot. A group of several feet constituted the section, and two sections entered into the line, a certain number of which were united into strophes or stanzas. A time value was given to all syllables and words

in the language; they were either long or short. A short syllable was equivalent to one time-unit, and a long to two. Various measures were employed. They might be equal to two, three, four, five or six time-units. The most common measures contain three or four time-units. The three time-unit foot most generally contains two syllables, one long and one short, or one short and one long. The four time-unit foot contains two or three syllables, generally two long, or one long and two short, or two short and one long. When only one long syllable occurred in the foot, it received an accent; when there were two in the foot, the first received the accent. The accented portion stood as the thesis, and the unaccented as the arsis. In the same way the two sections of the verse stood as thesis and arsis. The thesis came first. The middle pause did not usually divide the verse into two equal divisions. The first was the shorter, the pause coming within the third foot. Except as showing a perfect subordination to a chief accent, and a slight anacrusis at the close, the verses had no distinguishing marks; they were not rhymed, and very rarely alliterated.

The number of feet in a verse varied with different kinds of poetry, two being the smallest and six the greatest. The kind of foot with which the measure set out was not always maintained. Any other foot agreeing with the theme-foot in position of accent, and in the number of time-units, might be substituted. As such agreements in the kind of feet were few, there could be very little variety in the verse.

Greek poetry was not allowed to develop long untrammeled by rules. A rigid philosophical system was imposed upon it, and all future poetry was made to conform to this system. But it would be difficult to say that Greek poetry suffered from the restriction. It prevented novelty for novelty's sake, but allowed great freedom where freedom was most needed.

There are several facts in the history of rhythm that are interesting, both for the subject in hand and for psychology in general. Soon after the idea of varying the number of syllables in a foot had become known, and its effects appreciated, there arose a kind of mania for verses which contained a variety of feet. They were characterized as "tumbling verses" from the peculiar effect they gave rise to. This was a discordant and unpleasurable feeling. There was really no rhythm to them, and they never became popular. The same took place in regard to the length of line. Various novelties were introduced, when a longer line than that of the earliest poetry was found more pleasing and less abrupt. Verses of

six and seven accents were tried, and verses containing two sections, each of which was an alliterated couplet, having four or six accents, appear in some authors. No new combining agency was employed, and probably for that reason the verses exceeded the mental span. Had the older poets grasped the principles of unifying their lines by rhyme, or by proper subordination of the sections, they might have made such long verses a success. In the same line were the attempts at æsthetic forms, which have already been spoken of.

Experimental Investigation.

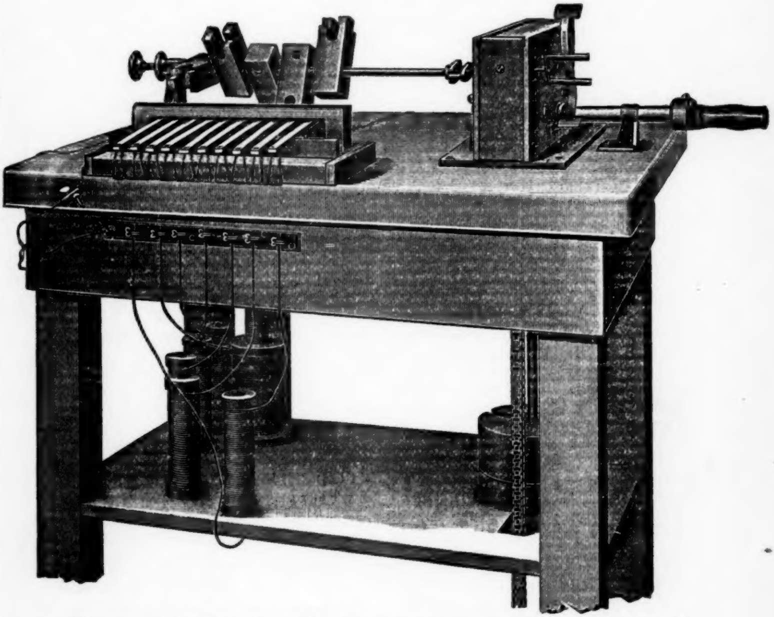
This work was undertaken with several objects in view. The first and most important object was to determine what the mind did with a series of simple auditory impressions in which there was absolutely no change of intensity, pitch, quality or time-interval. Each separate impression was to be indistinguishable from any or all the others. Regular variations with respect to the intensity or time-interval of the sounds in this series, which will be called a rhythmic series, were then to be tried separately and together, with the purpose of determining what values these properties of sound have in forming a rhythmical series—that is, a series of groups of impressions—out of a rhythmic series. It was seen at the outset that it would be practically impossible with the apparatus at our disposal to employ pitch variations, and for that reason no attempts were made with variations in pitch. Variations in quality or tone-color were contemplated, but the experiment was not carried out, first on account of a lack of time, and secondly of proper apparatus. The results of the first experiment anticipated much that was to be tried in the later experiments. As the work progressed, new problems were suggested for investigation until the narrow limits within which the work was begun were greatly overstepped. These problems will be taken up in what seems to be their proper order, and the results presented.

Apparatus:—The click of an electric telephone when connected in an induction circuit is constant in intensity, pitch and quality, when breaks occur in the primary circuit, providing the primary circuit is constant. The click is not the same in intensity when the primary circuit is made as it is when the primary circuit is broken. For this reason, the sound at the break only could be utilized. It is perfectly constant and stronger in intensity than the click at the make. It varies directly in intensity with variations in the strength

of the current and changes slightly in pitch and quality with variations of intensity, but the pitch and quality are always the same with the same intensity of current. A break at regular intervals in the primary circuit, when the secondary circuit is closed, the secondary circuit being open when the primary was closed, was all that was necessary to furnish the required series of auditory impressions with which the investigation might begin.

A chronograph after the pattern devised by Wundt[1] and

FIGURE I.



built by C. Krille, furnished a constant power. Figure I. gives a general view of the whole apparatus as it was used in this experimental investigation.

The drum-shaft was slipped off the drum and five arms, two and one-half inches long were put upon it by passing the shaft through a hole near one end. Each arm was provided with a set screw, that the arm might be held in position and

[1]This apparatus will be found fully described in the second volume of Wundt's Physiologische Psychologie, p. 279. 3d ed.

its position changed at will. They were set at equal distances apart along the shaft, and their points separated by 72 degrees, so that the space about the shaft was divided equally into five divisions. (See Figure II.) Corresponding to

FIGURE II.

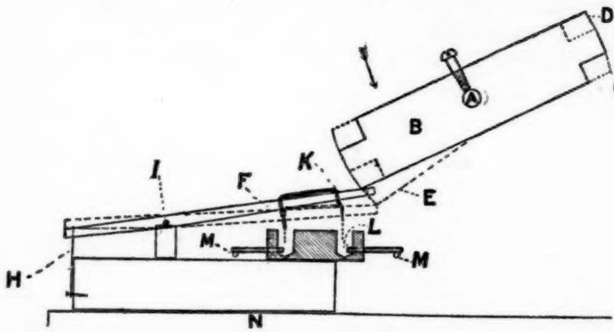


Figure II. shows the operations of the keys.
A. Drum-shaft.
B. The wooden arm on the drum-shaft.
C. The dotted line represents the following point of the arm.
D. The continuous line represents the leading point.
E. The dotted line indicates the position of the arm when the key is pressed down.
F. The key bearing the platinum points, which project below and are connected by the wire indicated by K. The dotted line below shows the position of the key when the platinum points dip in the mercury.
H. The rubber elastic which caused the key to react.
I. The rod upon which the key turned.
L. The mercury cup.
M. The wire connections.

each arm were two keys placed in such a position on the top of the chronograph that as the shaft revolved the ends of the arms came in contact with the ends of the keys and pressed them downward about half an inch to allow the arm to pass by in its revolution. The keys, which were ten in number, two to each arm, were made of strips of wood, six inches long and a half inch wide, and hinged horizontally upon a steel rod two inches from one end in such a way that the ends might move up and down. To the short ends were attached elastics, which caused the long ends with which the arms came in contact to rise up after they had been released by the arms on the drum-shaft. They were prevented from rising up too far by a piece of wood placed above them. Each arm

bore two points, the one about an inch to one side and ten degrees in advance of the other. The leading point came in contact with one key and pressed it down in advance of the other. As each point was broad, covering about twenty degrees of the circle described by the end of the arm, the first key would remain down until after the other had been pressed down. As both points upon each arm were of the same width, the key first pressed down would be released before the other. Near the long end, each key carried two platinum points which projected downward below the key, and which were connected at the upper ends by a wire. When the keys came down, the platinum points dipped into cups of mercury, which rested upon the top of the chronograph. (See Figure II.) These mercury cups were made by boring holes into the side

FIGURE III.

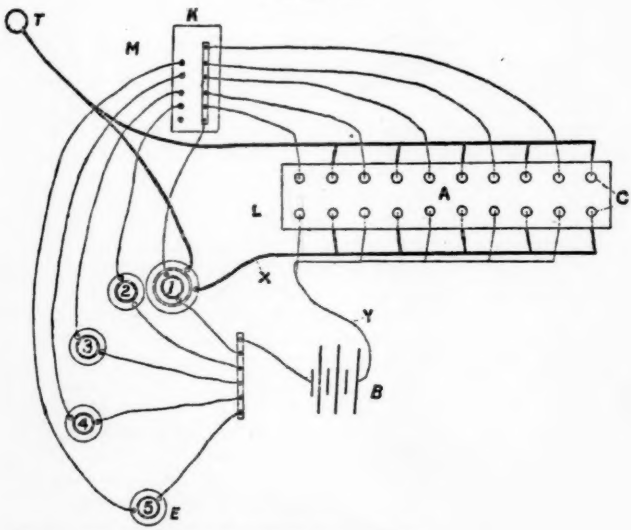


Figure III. shows the electrical connections.
A. The strip of hard rubber.
B. The battery.
C. The mercury cups.
E. 1, 2, 3, 4, 5. The primary coils. The double rings about 1 represent the induction coil.
K. The key-board.
The primary circuit is represented by light lines indicated by Y, and the secondary circuit by a heavy line, X.
T. The telephone.

of a strip of hard rubber, five-eighths of an inch thick. Holes were drilled into the edge of the rubber opposite the mercury cups and copper wires inserted, which were connected with the battery and induction coils in the manner which is schematized in Figure III. Beginning at the left hand end (marked "L") of the hard rubber strip, the first pair of opposite cups and each alternate pair along the strip were connected with a coil of wire on one side, and with the battery on the other. For purposes to be described later, were five coils of wire which might be connected with these mercury cups. The coil and the battery were connected, thus completing the primary circuit. The other pairs of opposite cups which alternated with these were all connected together on the one side with an induction coil, and on the other with the telephone. The induction coil and the telephone were joined, thus completing the secondary circuit. The ten keys corresponded to the ten pairs of mercury cups. When the first key at the left hand, and each alternate key thereafter, was pressed down by the arms on the drum-shaft so that the platinum points dipped into the mercury, it would close the primary circuit, for these keys joined the opposite mercury cups which were connected with the battery. When the second key at the left hand, and each alternate key thereafter was pressed down, it would close the induction circuit. Key 1 at the left hand end of the strip of hard rubber matched the first pair of opposite cups of mercury and was paired with key 2, which matched the second pair of the opposite cups of mercury. These first two keys were operated by the first arm at the left hand end of the drum-shaft. The other four pairs of keys were operated by the other four arms on the drum-shaft. Let us consider now only the first pair of keys and the first arm at the left. As the shaft revolves, the point of the arm which was in advance of the other was made to come in contact with the long end of key 1, and pressed it down. After coming in contact with key 1, the point of the arm could move through an arc of ten degrees, keeping the platinum points in the mercury, and thus closing the primary circuit, before the second point of the same arm would come in contact with key 2. When the keys were pressed down sufficiently to make the circuit, the points of the arm were made to slide by the ends of the keys in such a way that the key was not released until the arm had moved through an arc of twenty degrees. A further revolution of ten degrees by the arm would press key 2 down sufficiently to close the secondary circuit. If, now, the arm continues to revolve, key 1 would be released and rise up, breaking the primary circuit, but key 2 would

remain down while the arm moved through an arc of ten degrees, keeping the secondary circuit closed for a time after the primary circuit was broken. This would give a sound in the telephone. The same process would be repeated with each of the five pairs of keys and their corresponding arms. If, now, the arms were set at an equal number of degrees apart and the drum-shaft were made to revolve at a uniform rate, the clicks in the telephone would be separated by equal intervals of time, and not varying in intensity, pitch or quality, these clicks would form the required series of auditory impressions. If a change in intensity is desired, as it was, the five wires connecting the different pairs of mercury cups might each be connected with the five different coils which were referred to above. These were set at different distances from the induction coil (see Figure III.). As the different primary coils were of the same size, the strength of the induced current, and therefore the intensity of the sound, would depend upon the distance at which the primary coils were placed from the induction coil. They were placed at just sufficient distance apart to make the sounds easily distinguishable from one another in a graded series of intensities. By means of the key-board (marked "K") it was possible to connect all the five wires in any way that was desired with the five primary coils. The clicks might all be of the same intensity, all different, or of two, three or four different intensities. Whatever the variation, according to this arrangement it would recur every fifth click. When variations every fourth or third were desired, three or four arms were set upon the drum-shaft and only three or four pairs of keys operated. If the arms were separated by an equal number of degrees, the series of clicks would still be regular. Two kinds of arms were employed, those with a single end and those with a double end. (Figure II. represents the double ended arm.) By using both single and double ended arms on the shaft, and operating the five pairs of keys, it was possible to get an arrangement by which variations in intensity might occur every sixth or eighth click. Taking all the possible arrangements together, the operator might introduce a more intense click every two, three, four, five, six or eight clicks. Again, he might make a series of clicks which were composed of two, three, four or five different intensities of sound.

By making the number of degrees between the arms on the drum-shaft different, a difference in time-interval between the clicks was produced. In the same way as with the different intensities, a longer interval of time might be made to recur every two, three, four, five, six or eight clicks.

The rate at which the drum-shaft revolved determined the rate of the clicks in the telephone. This was controlled by the fan regulator upon the chronograph. Faster or slower rates were obtained by using smaller or larger fans. The rate was determined by counting the clicks in the telephone by a stop-watch. Rates between one click in two seconds and ten in one second were possible. As the rate was a very important factor, it will be given in all cases in the presentation of results. The "time" will indicate the interval between two clicks. The battery used consisted of 36 cells of the Watson's patent.

A further method of testing the accuracy of the setting of the arms upon the drum-shaft, which was done with a protractor, was to connect a time-marker in the primary circuit and take the record upon a drum along with a tunning-fork. It was found that setting might be accurate, but the drum-shaft might vary between one and two hundredths seconds in six seconds.

There is one particular in which an improvement might have been made in the apparatus. It was this: When the primary circuit was made, though the secondary circuit was open, a faint sound was heard in the telephone with close attention. The induction coil acts as an electric condenser, and the telephone being extremely sensitive, betrayed the presence of a weak current. This might have been avoided by making a break in both wires leading to the telephone, in such a way that the telephone would be wholly disconnected from the induction coil, when the primary circuit was made. During the entire experiment, only a single subject detected the presence of this sound, and for that reason it may be disregarded. The telephone was placed in a different room from the chronograph, where there was as little disturbance from other noises as possible, especially from any noises that were in the least suggestive of a rhythm.

When the experiment first began, the apparatus was set so that about three or four clicks to the second were heard in the telephone. The subjects were not informed in any particular in regard to the experiment. They were invited to be seated and listen to the telephone. This they did, taking very generally a rather critical attitude. They were then invited to say anything that suggested itself to them, whatever the character. These statements were all carefully recorded, and will be given in substance. The sounds suggested most generally and immediately the clock. Other suggestions were: slowly dripping water, galloping horse, pile-driver, etc. After the subjects had been seated for a time, during which it was apparent they were making a critical

study of the nature of the sounds, the statement most generally given, and voluntarily, was that the sounds were all alike, and seemed to be separated by the same interval of time. After this statement the subject paused, as if most that could be said had been said. In some cases they asked for particulars in regard to what they should look for. Sometimes, however, they went on to say that there was an apparent change of intensity in the sounds; the clicks seem to group themselves by twos or fours, as the case might be; generally, however, it required some kind of a suggestion to direct the attention of the subject to the grouping of the sounds. An indirect method was preferred to a direct one. In cases where the subject had spoken of the clicks seeming like the clock ticks, they were asked if there was the same difference of intensity or quality in the sounds as was apparent in the clock ticks. This suggestion was sufficient in many cases. The subject directed his attention then to the matter, and if there was any tendency to make groups of the clicks, it was apparent in a few moments. Sometimes it was remarked that they had noticed such a grouping, but had regarded it as a freak of their imagination, and did not think it worth mentioning. Another method of directing the attention of the subject to the grouping was to make a reference to the fact that they had said the sounds were all alike, and then to ask why they had said sounds and not sound; did they suppose there was more than one sound? In this case also, they replied frequently that they imagined that there was more than one sound, but did not think it worth while to mention the fact. In some cases it was sufficient to ask the subjects to count the clicks as they heard them, and then to ask how they counted. The reply was that they counted four or two, as the case might be, and then began again. Again it was noticed that the subject was unconsciously keeping time, with the foot tapping to every fourth or every second click. Such a subject was asked why he tapped every fourth or second click, and so his attention was directed to a grouping that was going on unconsciously. Such indirect methods were usually successful, but there were several cases in which indirect suggestions of this sort failed of their purpose. Direct methods of tapping a rhythm with the fingers or counting did not suggest anything beyond the clock tick to two subjects. These persons possessed no appreciation of music at all; they could not "carry a tune," and yet were able to recognize some of the common airs when they were sung or whistled. The general statement of the remarks and answers of each subject will be given as fully as it seems necessary. They will be abridged as far as possible,

but the special features in the answers of each subject will be mentioned. The treatment of special phases of these results will follow, and then will be taken up the result of special investigations that were suggested during the first part of the experiment.

Subject 1. Some musical talent and training.

Time, .23 sec. The first suggestion was a 4-group. Subject could suggest groups of two, three, five and six, but when he made no suggestion either by tapping or counting, he returned to a 4-group. The third in each 4-group was accented,[1] but it was possible in the later experiments to accent any member of the group. In general the first in all forms of grouping was accented. The 3-group was unpleasant and the 5-group was very difficult to maintain. Time, 1.14 sec. The most natural form of grouping was by two. It was possible to get a 4-group, but when the subject made no suggestion of any other group, he returned to the 2-group. Time, .167 sec. The 6-group was most easily suggested. It had the appearance of being composed of two 3-groups. The subject showed a tendency with this rate to group the 3 and 4-groups into higher groups. Eight-groups of threes and 4-groups of fours succeeded very well. It was not so easy or natural to make higher groups of fours. Time, 1. sec. This rate produced a drowsy feeling. The subject was inclined to make each click stand as the accented click in a 3-group, supplying the unaccented sounds between the accented in imagination. When the subject was tired he noticed a tendency to change the grouping frequently from two to three, and vice versa. The subject showed a strong tendency towards 4-grouping in preference to all other forms of grouping, and yet during one experiment, when the time was .208 sec., he found a 3-group more pleasant than either a 2-group or a 4-group. The rate was too fast for easy grouping by two. When he counted objects he counted them by fours. Time, .323 sec. The subject was disposed to make a 4-group, and, even when every third sound was made more intense than the others, he persisted in saying that he grouped them by fours, but that there was probably a longer interval in the series which disturbed the smoothness of his 4-groups. When his attention was called later to the accented clicks, he made no further mistakes of longer intervals for accented sounds.

Subject 2. Some musical talent and training. Accustomed to introspective work.

Time, .323 sec. The subject grouped by twos, visualizing the pendulum.[2] He could suggest groups of three and four easily, the four being more difficult than the three. Time, .263 sec. He grouped the clicks by four, but the 4-groups were divided into two 2-groups. Time, .208 sec. This rate yielded easily and naturally to a double 3-grouping. When he first listened to the telephone after

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[1] This accent consisted of an apparent increase in intensity with a change in pitch and quality.

[2] Almost every subject either visualized the pendulum or spoke of the pendulum-swing movement sometime during the experiments. In either case it was a form of grouping. When the rates were slow, the subject visualized the clock pendulum and made one click come near the completion of each half swing. The clicks were then grouped by two and were called the clock tick. In my own case and in some others there was a strong tendency to sway the body with the pendulum. This was called the pendulum-swing movement by the different subjects. It was quite visible at times. By this pendulum-swing movement groups of two, three, four, six or eight were frequently grouped into 2-groups. The first group, then, in the 2-group was accented or more emphatic than the other, and a distinct pause seemed to follow the second group.

either a change of rate or at the beginning of a new experiment, the clicks did not group themselves, but in a short time the tendency to group increased until it required the greatest efforts to hear the clicks as a uniform series. The subject was able to hear the clicks as a uniform series, only by imagining some one pounding in the distance. It required a mental picture of some objective thing that was perfectly uniform. When he gave himself up and listened to the series as a whole, he fell into some kind of grouping, which might or might not continue for any length of time. He had a strong tendency to shift from one grouping to another. He compared it to the optical illusion of the "stairs." The double 2-group is confounded sometimes with the double 3-group. Time, .187 sec. The subject said he got a compound 2 and 3-group, which by actual count of the accents to which he tapped with the fingers, showed he was making a double 4-group.[1] This subject was strongly disposed to double groups of all sorts. Time, .323 sec. At this rate the 2-group was most naturally accompanied by the mental image of the clock. Time, .263 sec. This yielded most easily to a 4-group, which took the form of two groups of twos. Time, .167 sec. This rate yielded at first to a 6-grouping, which was divided into two groups of threes, but it did not persist there; he returned to a double 2-group.

The pulse seemed at times to impose a grouping in which the clicks coming nearest in time to the heart-beat was accented. When the subject gave his attention to breathing, it more generally conformed itself to some grouping that was already going on. Inhalation lasted during a 4-group and exhalation during a 3-group.

Subject 3. Considerable musical talent and training.

Time, .5 sec. The subject's first suggestion was of a 2-group, but he immediately decided that a 4-group was more natural. He was able to count almost any rhythm at this rate as far as twelve, and the clicks seem to group themselves with the count. At first the groups were apparently separated by a longer interval, which the subject believed in the first place to be real. He was disposed to regard the 4-group as the most satisfactory. Any grouping was plainer when he counted. Diaphragmatic movements also accompany the grouping. With indifferent attention there was no grouping. The 4-group usually contained two accented clicks, either the first and the third or the second and the fourth. The former were preferred. This rate was found to be most pleasing. It was animating. The 5-group was difficult to get. A slight pause occurred between the groups in every form of grouping. In the presence of the chronograph, which gave a 6-rhythm which was composed of two 3-groups, the subject still grouped by four for a time, but this tendency was finally overcome and the series yielded to the suggestion of the chronograph.

When every fourth was accented, the subject being unaware of this accent, said that the 4-group only was possible, for there appeared to be a longer interval between every four clicks which made any other grouping impossible. When the accent was strengthened, he said the interval had been lengthened. This long interval might come anywhere within the group of four, but it more generally came between the groups. When two stronger clicks followed by two weaker ones formed the series, the subject said the

[1]It is not unfrequent for a subject to mistake the actual grouping which he is making. Sometimes a subject is so disposed to a particular number that he persists in saying that he gets groups of that number, when it is perfectly evident a greater or less number of clicks according to the circumstances is grouped with the accented clicks to which he taps.

rate was slower. He grouped the series by fours, but it appeared as though two long sounds followed by two short ones formed the group. When three strong sounds and one weak one formed the series, he still grouped by four. The first two in each group seemed to be of the same length, the third was longer and the fourth very short. During all the experiments the subject confounded stronger clicks with long intervals, and was never able to tell the difference between a strong sound and a long interval. He was surprised when told afterwards that the longer interval had been caused by accenting one sound. Time, 2.304 sec. The subject visualized the pendulum, but said the pendulum seemed to reach its full swing before the click corresponding to the swing was heard. The clicks seemed to delay too long. Time, .323 sec. Every third sound was accented. The subject had a strong mental habit for grouping by fours and was greatly puzzled by this accent on every third, which he said was a longer interval and broke up his tendency to form groups of fours. Time, .208 sec. Every third was accented. The subject forms 6-groups, which were accented upon the first and fourth and a long interval appeared between the groups of six. Time, .137 sec. When the series was composed of clicks of three different intensities repeating themselves in the same order, the 3-groups were again grouped by four generally, though the subject could suggest groups of three 3-groups.

Subject 4. Some musical talent.

Time, .288 sec. The clicks suggested the clock-tick. The subject could group them by twos, but he found it more natural to group by fours. It has long been a mental habit with him to make groups of four of any objects or impressions that would admit of any kind of grouping. He counts by four and groups the puffs of a locomotive by four. Four objects or impressions of any sort standing together have always arrested his attention. He found it possible to group these clicks by two, three or five when he made a suggestion either by counting or tapping with the fingers, but when the suggestion was stopped he returned to a 4-group. In every kind of grouping the first sound was always accented. Time, .115 sec. The subject said the grouping was by four and was requested to tap the accented click in every group. In six trials for five seconds each, he tapped just five times during each trial, showing he made a group of four in one second. The actual number of clicks to the second being 8.6, it was apparent that he was making a much larger group than four, probably an 8-group. When asked to make a 3-group and tap the accented click in each group, the results were nineteen taps in fifteen seconds, showing that his groups were not far from six instead of three clicks to the group.[1]

The 3-group was really a 4-group in many cases. Between each group of three occurred one click, of which no account was taken. It seemed to him something like this when he counted: 1, 2, 3, 1—1, 2, 3, 1—1, 2, 3, 1.

When the subject gave attention to the pulse, the number of clicks coming between the beats of the heart formed a group. The click which came nearest in time to the heart-beat seemed always to correspond to it. The breathing adjusts itself to the 4-rhythm. Inhalation lasts during one group of four, and exhalation during another. In this way the 4-groups were grouped by two. Time, .156 sec. By forming a mental image of the pendulum, or of some object moving up and down, he was able to make double 4-groups,

[1] It is probable that the primary grouping was two, and these groups of two were then united into larger groups of three and four.

which corresponded to the full swing of the pendulum. These three rates were given in rapid succession. Time, .536 sec. The 4-group was very clear. Time, .268 sec. The 4-group was unpleasant at first, but he gradually became accustomed to it. At first the rates seemed too fast. Time, .536 sec. With this latter rate the 4-group seemed to divide into two groups of two during the second trial. Time 1.072 sec. The 2-group seemed most natural and the subject felt a strong tendency to form higher groups of twos. After the subject became accustomed to this rate, he was more inclined to form 4-groups than 2-groups, but still the third and fourth clicks seemed at times more like a 2-group than a part of a 4-group. The general effect of this last rate was soothing. Time, 1.66 sec. This rate was soporific; it was possible to form a 2-group, but he did not do so spontaneously. Time, .323 sec. The subject grouped the clicks by four and found difficulty in suggest ing a 3-group. When every third was accented, he persisted in grouping by four. Again he was asked to suggest a 3-grouping, and he succeeded in doing so. The subject was unaware of the accent, and expressed surprise that he could group by three, and found it easier than grouping by four. The following rates were given in rapid succession. Time, .268 sec. The 4-group was very clear and pleasant. Time, .17 sec. The subject grouped by fours, but felt a confused irritating feeling. There was something added onto each group of four. Time, .134 sec. This rate recalled the sound of a locomotive. He visualized a revolving wheel, during each revolution of which he counted four. Time, .116 sec. He still groups by four, but the 4-groups are grouped by two, a strong and weak group together. When every eighth was accented, he grouped by eight. There was a distinct pause along with the accented sound. Time, .134 sec. Every eighth was accented. The 8-group divided into two 4-groups, with a pause after the second group. The 4-groups were grouped by two with the pendulum swing. Time, .268 sec. Every eighth was accented. The subject grouped by four and associated the pendulum swing with the groups of four.

Subject 5. Some musical talent.

Time, .288 sec. The subject was most naturally disposed to a 4-group, and found it difficult to get any other. Time, .78 sec. The 2-group was most natural with this rate. The 3-group was pleasant and easy when it was suggested. Time, 1.44 sec. It was easy to form 2-groups, but other groups were impossible. These three rates were given in rapid succession. Time, .353 sec. The 4-group was most natural. Time, .183 sec. The 8-group was most agreeable with this rate. Time, .156 sec. The subject found the 8-group most natural.

Time, .3 sec. When every fifth was accented, the subject made groups of four, accenting the four, and said that there was a rest between each group. He found it quite as easy also to accent the first. When his attention was called to this pause between the groups, he decided that the groups contained five clicks, in which the fourth was accented. When the first and third clicks were made more intense, the subject was greatly puzzled for a time, but decided that the series was compounded of a 2-group and a 3-group.

Time, .969 sec. He was able to form 3 and 4-groups. The series was associated strongly with the clock, and for that reason the 4-group tended strongly to divide into two 2-groups. Time, .323 sec. He found the 4-group most natural and pleasant, and when

he attempted to form groups of three, they would immediately run into fours. Time, .208 sec. The subject formed a long group of the clicks which he thought was an 8-group. The rate was too fast for easy grouping by four, and his attention seemed to waver between a 4-group and a longer one which he thought was an eight.

Subject 6. Some musical talent and training.

Time, .3 sec. When the subject first listened to the telephone he found no tendency to form groups of these clicks. Even after repeated suggestions the subject did not comprehend what was desired or to be looked for. He was asked to tap an accompaniment to the sounds with four fingers. After a time he found himself accenting the third, and grouping the sounds by four. When he tried the suggestion with three fingers it did not succeed very well. When two were tried, the subject decided that the 4-group was a combination of two 2-groups. In the same way he was able to group the sounds by six, but the groups divided easily into two 3-groups. On the whole the 2-group was the most natural with this rate. Time, .156 sec. The 4-group prevailed and easily combined into 8-groups. Time, .78 sec. The 2-group was most natural, but the subject was able to suggest the 3-group easily. Time, 1.44 sec. Even a 2-group was difficult to get. The time seemed to be too long. Time, .353 sec. Groups of two, three and four were all possible. The first click in all groups was accented, and the third also in the 4-groups. When he suggested a 6-group, it divided easily into two 3-groups or three 2-groups. The 8-group divided readily into two 4-groups. It was difficult to get a 5-group. The 5-group tended to run into a 6-group, which then divided easily into two 3-groups. Time, .288 sec. The 4-group was most natural, and readily combined into double 4-groups. Time, .156 sec. The 6-group was most natural. When the telephone was disconnected and the chronograph continued to run, the grouping always began with the first click in a new group. Time, .78 sec. The 2-group was the most natural. Time, 1.66 sec. There was no spontaneous grouping with this rate. It was too slow. The subject found it convenient to regard the click as an accented click in a 4-group, supplying the three intermediate sounds in imagination. Time, .323 sec. At this rate, the subject showed strong tendency to muscular movements, either to tap with the finger or toe upon the accented click, sometimes to nod the head or sway the body. He found this rate very favorable for voluntary changes of the grouping, which he did either by counting or tapping with the fingers. The general emotional effect was depressing.

The pendulum-swing movement or 2-rhythm was an important factor in all his groups. The 6-group was usually composed of two 3-groups, and the 8-group of two 4-groups. Time, .167 sec. The 4-group was very clear and pleasant, and the subject tended to group them by the motions of the pendulum. When every third click was strengthened, the subject grouped by threes, and made the 3-groups follow the motions of the pendulum. In this way the series produced an exciting effect. Time, .134 sec. The 4-group was plain and distinctly grouped by twos by the pendulum-swing. This rate was also exciting and animating. When every sixth click was accented, the grouping lost its exciting effect. When the series was composed of clicks of three intensities, the strongest first, the clicks were grouped primarily by threes and these 3-groups were again grouped into 4-groups. When the time was changed to .167 sec., and three grades of intensity retained, the higher grouping of 3-groups by four ceased. Time, .137 sec. When

every sixth click was accented, the series was grouped by six, and the six groups were again grouped by the motions of the pendulum. Time, .167 sec. Every sixth was accented. The grouping was still by six, but the 6-groups did not group by two. With the slower rate the 6-groups did not seem so compact as with the faster rate. Time, .208 sec. Every sixth was accented. The 6-group was difficult to grasp. The time was too long and the group tended to divide into two 3-groups. Time, .263 sec. Every sixth was accented. There was greater difficulty still in grasping the 6-group, on account of the tendency to divide the group into two 3-groups. Time, .323 sec. Every sixth was accented. The subject now grouped the series by four in spite of the accent upon every sixth. When the subject heard the sound of the chronograph, which was rhythmical, he grouped the clicks according to this rhythm, which in this case was a double 3-rhythmical. Time, .3 sec. Every fifth sound was accented. The subject grouped by fours, but the accent came in a different place in each group. It shifted one place further to the right. When a 6-group was suggested to the subject, the accent changed its position in the opposite way. It shifted its position one place to the left in each group.

Subject 7. Some musical talent and training.

Time, .3 sec. Almost immediately the series divided into groups of four, and soon after the 4-groups were grouped by two. With the suggestion of tapping, the subject was able to group by two, three or five. Time, .78 sec. The 2-group could be suggested only with difficulty. The 3 and 4-groups were not at all pleasant. Time, .156 sec. There was no distinct grouping. The series seemed to rise and fall in intensity at regular intervals. At times he had a "dreadful" feeling that the chronograph was slowing up and about to stop. The subject had observed this grouping of sounds in the puffing of a locomotive. He had not noticed a definite number in the group. The sounds simply rise and fall in intensity. Speaking of the 8-group, the subject said he had a feeling of not being able to "round up" until he came to eight. It seemed natural to stop at eight, and start over again. This group was accompanied by a feeling of completeness. During inhalation, the clicks seemed to come faster, and slower during exhalation. In all forms of grouping the subject felt a muscular sensation in the stomach and intestines. He also felt a strong tendency to beat time with the thumb. He had been taught to do so when quite young.

Four-grouping is a kind of mental habit with him. When the series was accented upon every fifth, he still grouped by four, making a pause between each group in which he pronounced the word "and:" 1, 2, 3, 4, and 1, 2, 3, 4, and 1, 2, 3, 4. In the same way the 3-group appeared as 1, 2, 3, 1,—1, 2, 3, 1,—1, 2, 3, 1. In the 4-group the first and third were always accented. In other groups the first was accented. When the rate was .72 sec. or .156 sec. the grouping did not come without suggestion by muscular movement or counting; with intermediate rates the grouping by four was wholly involuntary.

The subject could group 4-groups by two very easily, but it required an effort to group them by four, or 8-groups by two. The 8-group was generally composed of a more and a less emphatic group of four.

Time, .268 sec. A double 4-group was the most natural and easy. One group was more emphatic than the other. Time, .263 sec. Though the time was only slightly changed, the subject thought the previous double 4-group changed into a more perfect 8-group.

There was not such a strong division into two 4-groups. Time, .208 sec. This rate gave a "better 8-group" than the previous one. Time, .167 sec. The groups did not separate distinctly. There was a kind of confused feeling about the clicks. Time, .137 sec. The confused feeling with the previous rate was more apparent still. When every sixth was accented, he grouped by six and the 6-groups were grouped by two with the pendulum-swing movement.

Subject 8.

Time, .3 sec. The subject took a critical attitude. He had no preference for any grouping. He could count any number as far as ten, and the series seemed to group itself according to the count. In the longer groups, groups of two were frequent. Time, .156 sec. The 8-group was the most suitable. It was composed of two 4-groups, and each 4-group of two 2-groups. Time, 1.44 sec. It was not possible to form any grouping. The rate was too slow. The subject has noticed rhythms in the sounds of a mill-wheel, locomotives and fans. He was not aware of any definite grouping of the sounds.

Subject 9. Considerable musical talent. Long and careful training in music. Accustomed to introspective study.

Time, .3 sec. The subject adopted a critical attitude and gave his attention to the nature of the sounds. At first he was inclined to believe that they were all alike in intensity, but then he thought every third was stronger than the rest. For a time the interval between the clicks seemed to be irregular, but he soon discovered that this irregular interval might occur anywhere he chose to put it. In a short time his tendency to find groupings of the clicks grew so strong that it required an effort to hear the series uniform. Such an effort was akin to the feeling of "looking long into the future." The grouping tendency had to be restrained. Time, .3 sec. The 4-group was so plain that he did not discover the fact that it was imaginary and was completely surprised that the illusion was so complete. It was then more than ever an effort to hear a uniform series of single impressions. He said, "I find no rhythm as long as I hold my breath and stick to it." "I get hold of one click to compare it with the succeeding clicks, but I can't hold onto more than eight or nine." The simple suggestion of any grouping was sufficient to produce that grouping. Groups of two, three, five, six and eight follow immediately the suggestion of any of them. A group of seven was more difficult. Groups of all numbers were generally accented upon the first, but the accent could be voluntarily changed. In the 8-group the subject had a tendency to accent every other one. The grouping was generally accompanied by visible motions of the head and lips. A slight feeling of muscle tension in the ear and back of the scalp marked one group from another. There was a feeling of innervation of the muscles connected with attention.

When the attention was directed to respiration the grouping was not affected. Respiration was more inclined to follow the grouping. The heart-beat coming in about the same time as the accent in a 4-group, tended to coincide with it. Time, .2 sec. The tendency to group was still present in a small degree. The sound was quieting. It suggested slowly dripping water. Time, 1.5 sec. The suggestion was of a big clock. After listening to a fast rate for a time and then to the rate of .687 sec., he decided that he felt no tendency to group the sounds of the latter. Time, .116 sec. The most natural group was eight, with a slight tendency to divide into

two 4-groups. Time, .134 sec. The subject found a 4-group more natural than an 8 with this rate, but felt some tendency to make a double 4-group instead of a simple 4-group. Time, .116 sec. An 8-group composed of two 4-groups was most pleasant. Time, .268 sec. His most pleasant group was two, but these groups tended to combine to form double 2-groups. When two strong clicks followed by two weak ones formed the series, he grouped by fours, but accented the second and fourth. He described the phenomonon as a summation in the second: "The after-image of the first was left to the second to increase its strength." When the subject heard the rhythm of the chronograph, he grouped the sounds accordingly.

Subject 10. Some musical talent and training.

Time, .3 sec. The 4-group appeared immediately. The subject could suggest other groups of three, five, six and eight. The 3-group was accented upon the first, and the 4-group upon the first and third. During one experiment the subject said the accents in the 4-group were not distinguishable, but the groups were separated by a slight interval. The 5-group was accented upon the first and fourth, the 6-group upon every other one, and the 8-group was a repetition of two 4-groups. Higher groups of threes as far as four were easily obtained. The first and third groups of threes were accented. Higher groups of fours were not easy or distinct. During all the experiments unconscious movements in the tongue were present. A slight muscular contraction took place with the accented click. Other movements of the head, trunk, feet and hands were visible, and the subject found it difficult to restrain them. Time, .134 sec. These sounds were grouped by eight and the grouping was pleasant and animiating. Time, .156 sec. The first suggestion was of a 6-group. The 8-group was difficult. Time, .268 sec. This yielded to a 4-group, which the subject said required about the same time as the previous 8-group. Time, .78 sec. The 2-group was the only one practicable. The suspense for others was too great. Time, .116 sec. During this experiment the rate yielded most easily to a double 4-group, and when the time was changed to .45 sec. he had a similar feeling with the group of two, but one click stood in the place of the 4-group with the previous rate.

Time, .116 sec. Every eighth was accented. The subject got a very pleasant and "harmonious" 8-group. Time, .134 sec. Every eighth was accented. The subject was less animated. He said, "The group was more staid and steady. It had lost its tones." Time, .17 sec. Every eighth was accented. It now required an effort of attention to get the 8-group. It grew more pleasant as the subject became accustomed to it. Time, .268 sec. Every eighth was accented. The grouping was by four. Sometimes the subject accented every other one and felt disposed to count thus: one and two and three and four, and repeating this between the accented clicks.

Subject 11.[1] Some musical talent and training.

Time, .5 sec. The 4-group suggested itself immediately. The first and third clicks were accented, the first stronger than the third. Sometimes the third might be stronger than the first. It was possible to accent the second and fourth. When the subject gave close and critical attention to the sound, there was no tendency to grouping. The grouping seemed most clear with an indifferent state of mind. He showed a decided preference for 2 and 4-groups. Time, .25 sec. The 4-group was most natural. Time, .115 sec. This

[1]The subject knew beforehand that this was to be an experiment in the rhythmical grouping of sounds.

rate yielded to an 8-grouping, each group being composed of four strong and four weak sounds. At other times with this rate the sounds seemed to rise and fall at regular intervals, which the subject described as a waxing and waning of the attention. Time, .167 sec. The subject grouped by four, but felt a straining for a larger group. Time, 1.67 sec. He grouped by two and visualized the pendulum. One click came during each half swing. When the subject gave attention to his breathing, he made an inspiration last during the time of one click, and expiration during the time of another. The first click was louder than the last. Time, .115 sec. When the subject gave attention to his pulse the groups corresponded to the time of the heart-beats. The click which came near the beat was louder and became the first in the group. The pulse seemed to reinforce the sensation of the sound. When the attention was directed to respiration, the clicks increased in intensity during inspiration and were grouped by two and decreased in intensity during expiration. He visualized a curved line which rose during inspiration and fell during expiration. Smaller undulations in the larger curve corresponded to the 2-group. A melody always appears to him as a zigzag line, in which the rises correspond with every two notes. Time, .156 sec. He grouped the clicks by eight and visualized an ellipse with four points upon either side. The clicks seemed to locate themselves on these points.

The subject showed a strong tendency to muscular movements. He felt an impulse to dance, clap the hands and tap the toes and fingers upon the accented click. When the rate was .286 sec., this tendency to muscular movements was stronger than with the other rates. There was something animating about this rate.

Time, .3 sec. Every fifth was accented. The clicks were grouped by five. The accented click always appeared as the fourth in the 5-group and longer than the others. When this click was further increased in intensity, it seemed very much longer than the rest and appeared as an extraneous sound which did not enter into the group. The other four sounds then formed a group by themselves. When every sixth was accented, the accented sound again appeared as an extraneous sound. It simply disturbed his mental habits of forming some other groups. When two clicks in every five were made stronger with one weak click between the two strong ones, the grouping was still by five but it was a combination of a 2-group and a 3-group. When three strong and two weak clicks formed a group, it was composed then of a 3-group and a 2-group. The 3-group contained two strong sounds and one weak, and the 2-group one strong and one weak. A short pause came after the fourth sound, which made it impossible to make the 5-group appear as composed of a 2-group and a 3-group. Time, .268 sec. Every third sound was accented. This accent simply broke up the tendency of the subject to group by four and did not compel him to group by three. When every sixth was accented, he grouped by six, and accented the first and fifth, but there was a strain towards a 4-group. Time, .167 sec. Every sixth was accented. With this rate the 6-group was pleasant and did not tend so strongly towards a 4-group. Time, .137 sec. Every sixth was accented. The 6-group was pleasant, and it tended to unite into higher groups of two with the pendulum-swing movement.

Time, .208 sec. When the subject listened to the sound of the chronograph, which made a distinct and strong 8-rhythm, he was unable to form any other group than eight. The 8-group was composed of two 4-groups, the first of which was much stronger than

the second. When he listened to the chronograph, which gave a 6-rhythm, which was composed of two 3-rhythms, he was unable for a time to get anything but a 6-group, but this faded out with continued effort and gave place to his previous 4-groups. The 4-groups were then grouped by two with the swing of the pendulum. Time, .134 sec. Every eighth was accented. The grouping was by eight, and the 8-groups were then grouped by two.

Time, .116 sec. Every eighth was accented, and the grouping was by eight, and pleasant. Time, .134 sec. Every eighth was accented. The subject took no spontaneous interest in the 8-group at this rate. The period seemed to be too long. "It breaks off with a dead end," he said. Time, .17 sec. Every eighth was accented, but the grouping was by fours. The accented click was simply a disturbing element. The series did not group easily by either four or eight. Time, .208 sec. Every eighth was accented. The grouping at this rate was distinctly by four. The accented click acted somewhat as a disturbing element. When every fourth was accented at this rate, the 4-grouping became pleasant, and the accented sound was the first in each group. The 4-groups were grouped by two with the swing of the pendulum. Time, .17 sec. Every fourth was accented, but the time seemed to be too fast for a pleasant 4-group.

When every sixth was accented, and the time .323 sec., the grouping was by three, but the tendency to a 4-grouping was so strong that it was possible to get a 4-group in which every sixth sound was accented, the accented sound shifting its position in the group. The accented click seemed longer, and a longer interval followed it. When a very weak sound was followed by a very intense one, the sound of the loud click spread itself over the weaker one.

Subject 12. Considerable musical talent and great interest in music. Accustomed to introspective study.

Time, .3 sec. The subject began immediately to count the clicks, accenting every third. He unconsciously rocked himself in the chair to keep time. He thought the rate slowed up at times and then quickened again. The grouping was changed from three to four by simply thinking of the number. He believed there was some unconscious muscular movement about the change from one rate to another. He could suggest a change by simply tapping with his fingers. When he changed from a 3-group to a 4-group, the 4-group seemed too long at first, though he became accustomed to it. In a short time the grouping seemed to change of itself into three and then again into four. The 4-group was inclined to fall into two 2-groups, the subject unconsciously nodding his head to every other sound. He was able to suggest a 5-group, in which the first and third were accented, the third more strongly. He could accent any click in the group, but the first and the third seemed easiest. Time, .156 sec. The 6-group appeared immediately and spontaneously, and then broke up into two 3-groups. He suggested a double 4-group, which gave rise to a feeling of a slower pace. It was not so distinct as the double 3-group. This had a kind of impelling force. The subject attempted to step in time with the double 3-group, and then with the 4-group. The double 3-group required a sprightly step. It was exciting. The 4-group at this rate did not appeal to him; it didn't take hold. This rate was more stimulating than the previous one. Time, .115 sec. The subject dropped into a 4-group, but the three was found more stimulating. It was difficult, however, for him to put aside the

previous rate, and adapt himself to the new one. One click in each group, however, seemed distinctly louder than the rest. When he grouped by four, it easily passed into an 8-group, but the 8-group was not so clear as the 6-group. He imagined a wheel going around, making six clicks to a revolution. When he changed the telephone from one ear to the other, the grouping changed from six to a double 4-group, and persisted for a time. The 5-group came only with difficulty. Time, .76 sec. The grouping was by twos. The subject imagined the clock at home. The 3-group was suggested by an image of a musical conductor beating time. Time, 1.44 sec. The subject gets the rhythm of the pendulum swing without suggestion. He suggests also a 3-group, which recalls the time of church music. Time, 1.66 sec. He finds it easy to imagine intermediate sounds between the actual clicks, and these he groups by three, the real click being the accented click in the 3-group. Time, .286 sec. In order to obtain a notion of a rhythmic series—one of uniform intensity—the subject turned his attention backward, and saw a series of images to which he was adding one all the time. He throws his attention upon what comes, and studies the nature of the noise to see if the timbre is the same. It is a comparative effort. But in spite of all efforts the series groups into a 2-group at times. When a relay sounder was connected in the circuit of a vibrator, which made 20 vibrations to the second, the subject was still able to effect a grouping of the sounds into either 3 or 4-groups by tapping with the fingers upon the table. When he dispensed with the suggestion, the clicks of the relay signal were perfectly uniform, except perhaps a slight waxing and waning in intensity, due probably to the waxing and waning of the attention towards the sound. There was no real grouping.

When a longer interval was introduced every fourth, the clicks came in a group of four, but there was nothing satisfactory about the group. The clicks did not form an organic group. Each group of four stood rather as a single compound impression. There was no organic relation between the separate clicks in the group. When the rate was rapid, the groups of four were grouped into higher groups, the groups of four standing as single impressions. When the rate was slow the long interval might come between the groups or anywhere within it. There was something wanting, something to be looked for in the interval.

As the nature of the group, the subject described his feeling as a tendency to go back when he had heard three or four clicks, as the case might be. He says he has a "mouthful"—a unity—and when he has one, he seeks to get another. The same process continues to repeat itself. When he directed his attention to the timbre of the click, he got no grouping, but when he looked at the series as a whole, the grouping was clear and spontaneous. There was not, however, necessarily an accent in the group.

Subject 13. Considerable musical talent and training. A lover of 2-4 music.

Time, .285 sec. It suggests the gallop of a horse— a short gallop —and the clock. There is a breathless feeling about it. It is the sound of car wheels—the whole train. It has a double vibration. The clicks are grouped by two or by four. The group seems to close with a rising inflection; the last is apparently accented lightly, as the first is strongly. The 2-group prevailed over the four. Parts of "Erl King" are suggested by this grouping. An objective suggestion was displeasing to the subject. The subject preferred a mental suggestion in order to change the grouping from two to anything that was desired. By such a suggestion the sub-

ject was able to get most any group up to eight. The eight group was not clear; the accents were not sufficiently prominent. The shorter measures are more strongly accented. Time, .115 sec. This rate had a bad effect; it was tormenting. The grouping was by four of a particular pitch, followed by four of a lower pitch. The subject might group the clicks by two in the same way, but with less clearness. Time, .352 sec. This rate suggested something going around, and every other sound was accented. When the 3-group was suggested, the first click was accented, and the group closed with a rising inflection. Higher groups of 3-groups could be obtained as far as four. The groups seemed to rise and fall in intensity. At this rate also the short groups were more strongly accented than the long. When the subject suggested a 4-group, the first and the third were accented, the first probably stronger. The 4-groups may be grouped again by four. Twenty was the greatest number of clicks that the subject could grasp easily in this way. The grouping becomes lost and disconnected with larger numbers. The first groups in the larger groups were of greater intensity, and the last of a lesser intensity. The intensity of each succeeding group seemed to be less. This rate was said to have the most "æsthetic effect." Time, .268 sec. The 2-group was most easy; a double 2-group was pleasant. The general effect of this rate was a hurried feeling. The previous rate had been restful. Time, .156 sec. The 4-group was most natural, and was accented upon the first and the third. The 6-group appeared without voluntary effort. There may have been a mental suggestion of the six. Time, .78 sec. There was no real grouping. It seemed painfully slow. Time, 1.44 sec. The subject supplied two intermediate sounds between the clicks, and grouped by three. The actual click was the accented sound in each group, and came first. Time, 1.66 sec. The subject supplied three intermediate sounds between the clicks, and grouped by fours. The real sound came first. Time, .134 sec. The double 4-group was most natural, and the subject breathed with it. When every eighth was accented, the subject did not become aware of the accent. The grouping was spoken of as being so strong that it could not be gotten rid of. The groups of eight were grouped by two with the swing of the pendulum. The clicks in the 8-group seem to decrease in intensity from the beginning to the end. Time, .116 sec. Every eighth was accented. The movement was the same as with the previous rate, or perhaps in place of the pendulum movement the subject visualized an object moving up and down, the upward motion lasting during the time of an 8-group, and the downward motion during another 8-group. There was apparently a longer pause after the second group. The subject felt a strong tendency to nod the head, and keep the time by tapping the toe. Time, .17 sec. Every eighth was accented. The 8-group lacked completeness. It was not so smooth as the 8-group before; it was distinctly divided into two 4-groups. The accented sounds were generally unpleasant. The subject "has not the restful impression of evenness" which had characterized the uniform series.

Time, .323 sec. When the clicks were all of the same intensity, the slightest suggestion of any sort was sufficient to cause the clicks to fall into the group suggested. Even when the attention of the subject was not called to a suggestion, and the subject apparently did not attend, it would change the grouping to that suggested.

At times the subject had a feeling which was described as "awful," that the chronograph was slowing up and about to stop. When stronger clicks were introduced, the effect was unpleasant.

The following rates were given in rapid succession: Time, .268 sec. The clicks were grouped by two, and the 2-groups seemed to rise and fall in intensity at regular intervals. Subject could suggest other groupings, but it drifted back to this, unless the subject kept up the suggestion of some other. Time, .208 sec. The grouping was by four. The rate was unpleasantly fast for a time. Time, .134 sec. The grouping was by four; the 4-groups seemed to rise and fall in intensity, every other one being more intense. The subject unconsciously breathed with this secondary grouping. Every eighth was made more intense. The subject did not detect the accent, but said the grouping by eight was so clear that it could not be avoided. The 8-groups tended to group into 2-groups. Time, .116 sec. Every eighth was accented. The clicks were grouped by eight, and the 8-groups were grouped by a wave-like motion. There appeared to be a longer interval between every two groups. Time, .17 sec. Every eighth was accented. The grouping was primarily by two, and the 2-groups were grouped by four. The intensity of the clicks seemed to decrease from the beginning to the end. The grouping was rough in comparison with that for the previous rate. This form of grouping gave place finally to a double 4-grouping, and the subject was strongly inclined to keep the time by nodding or tapping with the toe. Especially strong was this impulse when strength of the accent was increased. Time, .208 sec. Every eighth was accented. The 8-group was now more distinctly divided into two 4-groups. This grouping had more "dignity and force, but was not so tripping as the fast rate was." The 8-group was not so complete as it was with the faster rates.

Subject 14. Some musical talent and training.

The first suggestion of a grouping was by eight, and the 8-group was divided into two 4-groups. When a 2-group was suggested the subject agreed that he could get it, but the 2-groups were again grouped by two into 4-groups, and the 4-groups by two into 8-groups. A 6-group was suggested by counting six, but there seemed to be a division corresponding to 4-groups. The subject was under the impression for a time that there was a longer interval or four different intensities of sounds which made this 4-grouping. The 4-group was accented upon the first and the third. The 3-group did not succeed very well. The subject seemed to have a habit of forming groups of two, and the strongest kind of a suggestion was not sufficient to put it aside for a 3-group. Time, .156 sec. The 8-group, which was divided into two 4-groups, was the most natural, and seemed to prevail over all others. Time, .78 sec. The 2-group was most easily obtained, but it was possible to suggest either a 3-group or a 4-group. The subject was not sure whether he preferred a 2-group to a 4-group. He also found the 3-group quite pleasant. Time, 1.44 sec. The 2-group was most natural, and the subject could still suggest either a 3 or a 4-group, but when he dispensed with suggestion, he returned to the 2-group.

The subject has noticed rhythms in the sound of mill wheels. When he gave his attention to these sounds he visualized a series of points on a line which he counted by four or two. When he was asked to count a series of dots, he said they were divided off into twos by a bracket above them. It has always been a habit with him to count objects by two.

When every fifth was accented, he grouped by five; the accented click came fourth in the group, and it seemed longer than the rest. When the accented click was made more intense still, its time seemed longer than the rest. When one of the five was made

weaker than the rest, they formed a somewhat irregular group that was unpleasant. The weak sound caused a disturbance in the group which was not present when a louder sound was introduced. When all the clicks were made more intense, the rate seemed to be slower than at other times.

Subject 15. Some musical talent and training.

Time, .3 sec. The sound suggested the clock. It was more easy and natural to regard every other one stronger. Groups of three, four and five were suggested. The 4-group was the most natural; the first and third clicks were accented. At times the 4-group seemed to divide into two 2-groups. When the subject attempted to compare the 3-group with the 4-group in point of their agreeableness, the three group appeared as three, with one sound coming between the groups, thus: 1, 2, 3, 1,—1, 2, 3, 1,—1, 2, 3, 1. This extra sound seemed to occupy a blank space between the three groups. During other experiments afterwards, the 3-group appeared in this form. The 4-groups were easily grouped by two. They would combine into no higher groups as simple 4-groups. The subject was able with great effort to combine two double 4-groups. When the subject counted objects, he usually grouped them by twos. The objects seemed to be joined together by bars. Time, .57 sec. This rate was very quieting. The 4-group was most natural. The first and third or the second and fourth might be accented. A longer interval appeared between the separate groups. A long interval generally follows the accented click whether it is imaginary or real. The subject regards real accents as extraneous intruders. They introduce a long interval, and for that reason the series seems irregular. By irregularity he understood a difference in time interval of the clicks. The accented click seemed nearer to the preceding click than the others. When two real accents of unequal intensity were put into a group of eight, the interval following the more intense click was the longer, and gave to a series a very irregular appearance. When the accented clicks were dropped out, the series became regular again.

Time, .268 sec. This rate was very favorable for voluntary changes of grouping. He could suggest any grouping that he might desire within limits. During every experiment the subject manifested a strong tendency to some kind of muscular movements. Any kind of muscular contractions would suffice as a suggestion of a grouping. He said he either counted the clicks or made the proper muscular adjustments for counting. There was mental counting always at the start. He made unconscious movements with the eyelids. Motions of the head were clearly visible the whole time. When the subject was asked to restrain all movements of which he was conscious, he said there was great difficulty in keeping the grouping. The telephone was disconnected, and the subject was requested to restrain his muscular movements or attempts to count. When the telephone was connected again, he said that the grouping had kept up during the interval. Although he had restrained all visible motions, slight muscular contractions were observed in the eyelids at the proper intervals of the accented clicks. He said it was possible to keep the grouping by imagining a series of colors passing before the eyes. He spoke of a feeling in the eyes as "muscular color sensation." He seems to have felt an adjustment of the muscles ordinarily used in visual attention. At no time was he conscious of the muscular contractions of the muscles in the eyelids.

Time, .57 sec. Every fifth was accented. The series was grouped by five and the accented click came anywhere in the group. It was

more generally and naturally near the first place. Time, .268 sec. The 3-group could be suggested, and was more naturally accented upon the first, sometimes upon the third. The 6-group was strongly accented upon the third and slightly upon the first and fifth. With a uniform series, the 5-group required a distinct effort and was then accented upon the last. In general the long and complicated groups were less differentiated; they ran together. The 6-group broke up into two 3-groups and the 8 group into two 4-groups. A 7-group was very difficult to get. It would run readily into an 8-group. Time, .134 sec. Every eighth was accented. The 8-group was pleasant at this rate. When the time was .116 sec. and every eighth accented, there was a tendency to group the 8-groups by two. During a subsequent experiment when the time was .116 sec., the series seemed to rise and fall in intensity with no definite grouping. Whenever an accent was put in, it made the series irregular and unpleasant. The series became pleasant in proportion as it was uniform, and with this rate the subject perceived only a rhythmic rise and fall in intensity.

Subject 16. Considerable musical talent and training.

Time, .3 sec. His first suggestion was that every other one was stronger in intensity, the stronger one coming first in the group of two. For a time, the subject did not discover that the sounds were uniform. He could suggest a 4-group, in which the first and third were accented, the first stronger than the third. It was difficult to get a 5-group, but when the subject did, the accents were upon the first and third. The 2-groups might be grouped by fives, in which case the first and third 2-groups were more intense than the others; 4-groups of twos were accented upon the first and third 2-groups; 2 and 3-groups of twos were accented upon the first. Higher groups of 3-groups as far as five were possible. The accents were the same as for higher groups of twos. Three-groups of three were the most pleasing. Higher groups of four were more difficult. The accents could not be kept clear. From early childhood, the subject has observed and taken pleasure in the rhythms in the sounds of the fanning mill, feed cutter and other machinery. The 4-rhythm was the prevailing rhythm with him. The puffs of the locomotive are grouped by fours, the first and the third being accented, the first stronger than the third. He associates the pendulum with the 2-group. With the 4-group, he associates the locomotive or a wheel turning around, making four sounds to each revolution. The 3-group generally requires attention to keep it and a suggestion to begin. The 5-group breaks up into a 2-group and a 3-group. The 6-group generally divides into two 3-groups. Time, .176 sec. This rate seemed most favorable for a 6-group. It was composed of two 3-groups, the subject visualizing the pendulum which grouped the 3-groups by two. In general, the subject preferred short groups to long ones. The shorter groups were simpler. He preferred also his own accents to real accents. When he listened to the sound of the chronograph, which was distinctly rhythmical, he grouped the sounds accordingly. When he was dull and tired, faster rates were generally more satisfactory.

The following rates were given in rapid succession: Time, .323 sec. The clicks were grouped most easily by the pendulum-swing movement. The subject could visualize a revolving wheel which made four strokes during each revolution and thus group by four. Time, .263 sec. The 4-grouping was decidedly pleasant and compelling. It required an effort of attention to group by three. He visualized the locomotive wheel with the 4-group. He could group the clicks by two with a pendulum-swing movement, but "it was

too fast to be real natural." Time, .137 sec. This was "a train at full speed." The rate was more pleasant and enlivening than any previous rate. It required very little effort of attention to get either a 3 or 4-group. A 6-group was easily suggested, but the group divided easily into two 3-groups. Time, .208 sec. The 6-group was less easy than it was with the previous rate. Time, .137 sec. The clicks grouped readily by three or four. Higher grouping of 3-groups by two or three required a suggestion to start, and it seemed to continue of itself; 4-groups might be grouped by the pendulum-swing movement. Every sixth was accented. The 6-grouping was necessary and pleasant. The accented sound took away the effort that had been required before for a 6-grouping. The 6-group might be divided into three 2-groups or two 3-groups. The accented sound always came at the beginning of the 6-group. Time, .167 sec. Every sixth was accented. The 6-group divided easily into three 2-groups or two 3-groups. Time, .323 sec. Every sixth was accented. The grouping was by two. The accented sound grouped the 2-groups by three. The span for a 6-group was disagreeable. It was too long. The accented sound might be overlooked and the series grouped by four. Time, .167 sec. Every sixth was accented. It was less easy to overlook the accented click than before. The accent forced a grouping by three.

Time, .263 sec. It was most natural to group by two with the pendulum-swing. Time, .208 sec. A 4-group was most easy. When the subject heard the chronograph, which gave a 6-rhythm compounded of two 3-rhythms, he grouped the sounds accordingly. Time, 134 sec. A 3 or a 4-group was equally pleasant and easy. The sound of the chronograph, which now gave an 8-rhythm compounded of two 4-rhythms, compelled a grouping of the sounds accordingly. The following rates were given in rapid succession during a single experiment: Time, .268 sec. A 2 or a 4-group was easy. A 3-group could be suggested. Time, .208 sec. A 3-group was suggested, but a 2 or a 4-group was easier. Time, .17 sec. A 3 or a 4-group was equally pleasant and easy. There was no preference. Time, .116 sec. The series could be grouped by three or four. When every eighth was accented, the grouping was by eight. At first, the 8-group divided into two 4-groups. This disappeared, and the 8-group became pleasant and agreeable. Time, .134 sec. Every eighth was accented. The 8-group divided easily into two 4-groups. The span was too long. There was no satisfaction in the 8-group, for the accent did not come soon enough. Time, .208 sec. Every eighth was accented. This was distasteful. The feeling of suspense present before was greater still. Time, .268 sec. Every eighth was accented. The suspense was still greater, and the 8-group broke up into two 4-groups. Time, .116 sec. There was no accent. This rate, which had given before an agreeable 8-group, when every eighth was accented, yielded to an 8-grouping. There was a slight tendency for the 8-group to divide into two 4-groups, the first of which was more emphatic.

Subject 17. Some musical talent and training. Accustomed to introspective study.

Time, .3 sec. In the first place, the grouping was by two, and almost immediately and without effort it changed to a 4-group. When each click was attended to separately, they all appeared to be of the same intensity. Suddenly the subject began to group by four. He felt a tendency to count it off to himself. Sometimes the 4-group appeared as two 2-groups. Then he thought there was an irregular interval—a difference in the time of the clicks. He then imagined that a fainter sound was heard between the actual clicks.

Each click was grouped with the fainter sound following it, and these groups grouped by two. Breathing seemed to accommodate itself to the 4-group; inhalation lasted during one group of four and exhalation during another. When every third was accented and time .208 sec., the subject felt a strong tendency to inhale during one group and exhale during another.

Each group is attended with the feeling of having completed a member of the rhythm. The groups stand out as unities—as wholes—and as each group becomes complete, there is a striving for the next. The subject has a tendency to count the clicks by fours or other numbers. When he attempts to suggest a 3-group, the third click seems to repeat itself thus: 1, 2, 3, 3,—1, 2, 3, 3,—1, 2, 3, 3. He succeeded, however, in getting a real 3-group by counting and nodding the head with the accented click. When he attempted to group by five, the accents seemed to crowd along until it brought six into the group. The first three clicks seemed to come in the time of two and the rest were irregular. When he succeeded in getting a 5-group, it was accented upon the second.

Time, .965 sec. The 2-group was the most natural, but it was imperfect. Time, 1.615 sec. The subject was able by strong effort to group by two, but the sounds seemed more naturally to appear uniform.

Subject 18. No musical talent and no interest in music.

Time, .352 sec. This was a very pleasant rate. Other rates seemed either too slow or too fast. By no suggestion could any kind of grouping of the sounds be effected. The subject declared that they were all uniform in intensity.

Subject 19. Some musical talent and in training at the public school.

Time, .268 sec. The subject likened the series to dropping water. It was suggested to him that perhaps some sounds were louder than others, when he said that every fourth seemed louder. Again it was suggested that possibly every third was louder, but the subject would not agree to it. When every third was strongly accented, the grouping was by three. When the accent was dropped out, the subject returned to a 4-group. When he listened to the sound of the chronograph, which was making a double 3-rhythm, he grouped the sounds accordingly.

Subject 20. Some musical talent and good training.

Time, .268 sec. The sound was likened to dropping water. It was suggested that the clicks grouped together in some way, and the subject replied that they were grouped by four. Again it was suggested that some other grouping was possible. This, the subject said, was by three. After reflecting and counting for a moment, the grouping was thus: 1, 2, 3, 1—1, 2, 3, 1—1, 2, 3, 1. The first and third were accented in the 4-group.

Subject 21. Physicist.

Time, .30 sec. The sound suggested the pendulum. A loud click corresponded to one swing and a soft to the other. He visualized a conical pendulum, which struck at several points in its swing and thus grouped the sounds by other numbers than two. He seemed to attend now to the series of clicks and then to relax and attend again. During the "strains of attention," he might grasp three or four clicks. A feeling of relief followed each strain of the attention. All the muscles of the body seemed to point toward the source of the sound. They alternately contract and relax with the successive strains of the attention. The first click in each group was accented.

Subject 22. Some musical talent.

Time, .3 sec. The clicks were grouped by four. Time, .78 sec. This rate was too slow for any grouping. It did not even suggest the clock tick. Time, .156 sec. This rate was too fast for easy grouping in any way.

Subject 23.

Time, .268 sec. The prevailing group was four. It was difficult to suggest any other. The sound of the chronograph, which gave a 6-rhythm compounded of two 3-rhythms, was scarcely sufficient to break down the tendency to group by four. The subject had worked in the same room with the chronograph, and had become more accustomed to the 8-rhythm than to any other which the chronograph made.

Subject 24.

Time, .268 sec. The clicks grouped immediately by two. There seemed to be a difference in quality. When every fourth was accented, they were grouped by four. A longer interval preceded the accented click. When every eighth was accented, the clicks were grouped by eight and a longer interval preceded the louder sound.

Subject 25. Some musical talent and training.

Subject has noticed his tendency to group objects and sounds before the experiment. Objects passing rapidly before the eyes are grouped by eight, those passing slower, by four, and those passing very slowly, by two. Time, .78 sec. Every other sound appeared to be of sharper tone than the rest. The sharper toned click grouped with a weaker and came first. Time, .115 sec. He grouped by eight. When he gave attention to the pulse, he seemed not to hear the clicks coming near or just after the heart-beat. The clicks between the heart-beats were more distinct. No grouping of the sounds would persist long. The accented sound in the group generally came first, but it might come anywhere in the group.

Subject 26. Some musical talent and training. Laboratory boy.

Time, .323 sec. The most natural form of grouping was by two. The first was accented. When he suggested a 3-group, the rate seemed to be slower, and then the clicks seemed to be of the same intensity. When every third was accented, the accented click came first in the group, and was preceded by a longer interval. In whatever position an accented click stood, it was preceded by a longer interval. With uniform sounds the 4-group was accented upon the first and third; the first was stronger than the third.

Subject 27. Some musical talent and training.

Time, .3 sec. The most natural form of grouping was by two. The first was accented. He was able to suggest groupings by three or four. The first sound in either group was accented. By tapping with five fingers, and striking much harder with the fifth he was able to suggest a 5-group. It seemed to be a matter of the imagination largely whether there was a rhythm. When he thought of a clock or some other rhythmical machine, the series tended to group according to the suggestion. The sound was most naturally associated with dropping water.

Subject 28. No musical talent.

Time, .536 sec. It was possible to group the series by three, four or five. The 4-group was most natural. From early childhood the subject has observed the 4-rhythm in the puffing of the locomotive especially, and in later years the same rhythm has been observed in clocks, metronome, hammering, walking, and in all auditory impressions that approach a regularity in sequence. The rhythm is clearest in the sound of the locomotive. The first and third

sounds in the group are accented; the first is generally more strongly accented than the third. When the sounds of the locomotive become very rapid there is no definite grouping, simply a periodic rise and fall in intensity. Time, .268 sec. This was especially favorable for the 4-group, and the 3-group could not be easily suggested. Time, .208 sec. The 4-group was most natural. It was possible to suggest a 2-group by striking heavily on every other sound. The grouping, however, was very monotonous. Both the 3 and the 5-group were very difficult. Time, .268 sec. Although the 3-group was difficult at this rate before, it could be easily suggested this time. Time, .17 sec. The clicks were grouped by four and the 4-groups tended to group by two with the pendulum-swing movement. If the grouping was held down to a plain four, it became unpleasantly monotonous. Time, .134 sec. The series tended to appear in the form of a periodic rise and fall in intensity. The periods were about equal to the time of an 8-group, and with a slight voluntary effort the series grouped by eight. The 8-groups tended to group by two with the pendulum-swing movement. During a subsequent experiment with the same rate, the subject felt a tension in the eye muscles which grouped the series by eight; four sounds occurred during the upward movement and four during the downward.

Subject 29. Some musical talent and training.

Time, .268 sec. When the subject thinks of a clock the series groups by two, but when he thinks of hammering, the clicks appear to be of the same intensity. He could suggest a 3 or 4-group, but the 2-group was most natural. Time, .208 sec. He finds it easy to count almost any rhythm as far as nine. The longer rhythms tend to divide into shorter ones. The subject found it difficult to keep from thinking of a clock tick, which suggested the 2-group. Time, .17 sec. The subject still grouped by two and thought the rate seemed to be faster when he grouped by two than when he suggested other groups.

Subject 30. No musical talent.

Time, .268 sec. By no suggestion was it possible for the subject to effect any kind of grouping of the sounds. It appeared as a dead monotonous series, with which he could not avoid the association of a pile-driver.

Many other persons who simply came in as visitors, were experimented upon with results which confirmed the foregoing records. No especial account was taken of them. More than fifty persons in all were experimented upon, and only two failed to effect some kind of grouping in the clicks which they heard. In general it may be said that the younger and less educated yielded more easily and quickly to the suggestion of a rhythmical grouping.

The first point in the preceding records to which attention is called is the rhythmical grouping of the sounds. The grouping was the same in every case. It was accomplished by accenting regularly certain sounds more than others. The weaker or less accented sounds seem to run together with the stronger, and to form organic groups which are separated from one another by intervals which are apparently longer than the interval which separates the individual clicks. Such rhythmical grouping has been observed frequently at other times by many persons. Several of the subjects testify

to have known of their tendency to group the puffs of the locomotive, even in early childhood, and they have taken great delight in it. With us this habit of grouping the puffs of the locomotive when it was starting slowly or pulling up a grade became so strong, even in early childhood, that it led to all kinds of speculation as to the cause. The puffs are grouped by four. The first and third are accented, the first generally stronger than the third. No other grouping ever seemed possible until it was found in the experimental work that the tendency to group by four was only a habit or association. The puffs of a locomotive may now be grouped by two or three, but the association of the drive-wheel making one revolution to four sounds renders any other form of grouping than by four difficult. When the engine runs very fast, the sounds seem to rise and fall in intensity at regular intervals.

A kind of rhythm is also observed in the noise of mill-wheels. The winnowing machine and feed cutter, such as are found upon many farms, produce a rhythmical sound which few persons fail to observe. Long association in early childhood with such rhythms stamps them upon the mind so firmly that they become a mental habit. Children either fancy or perceive rhythms in many sounds; they indicate this by their attempts to reproduce the sound of machinery or of locomotives. Some railroad engineers believe their engines sing tunes. The same engine under like circumstances always sings the same tune.

Several experimenters have also observed this same grouping of rhythmic sounds. In the work undertaken by Dietze[1] in Wundt's laboratory upon the *Umfang* of consciousness, this rhythmical grouping of the sounds of the metronome was observed and employed to determine the length of the mental span. The grouping was accomplished by intensifying voluntarily certain sounds and subordinating others to it. By grouping the sounds first by eight and then the groups of eight by five, it was possible to grasp forty sounds. Wundt says it is impossible to restrain this grouping absolutely. It may be confined to a 2-group, beyond which it cannot go within certain limits. Four sec. is the lower limit, and .11 sec. is the upper limit. The most favorable rate is .2 to .3 sec. Wundt refers this grouping to the ripening of the concept on the wave of apperception. As we shall see later, it is possible to restrain this tendency to group sounds. The difficulty was with Wundt's apparatus. The two sounds heard during a complete swing of the pendulum

[1] Wundt, Physiologische Psychologie, Vol. II. p. 73.

of the metronome are not of the same intensity or quality, and hence the impossibility of restraining the grouping by two.

Angell and Pierce,[1] in their experiments upon attention, state that one subject noticed a rhythm in the sounds with which he felt a tendency to muscular contraction—nodding of the head and beating time with the fingers.

In neither of these experiments could the experimenters be sure that there was not some difference in the sound which would suggest a rhythm. The importance of an absolutely uniform series of sounds cannot be too strongly insisted upon. A difference in sounds which would ordinarily remain unnoticed, is sufficient to suggest a rhythm. This will be seen when we come to discuss the voluntary changes of the grouping and the ease of suggesting such a change. In the present experiments the greatest precaution was used against any variation in the sounds that would suggest or impose a grouping. The only possible source of such a variation would come from a difference in the resistance between the mercury and platinum. If the mercury were dirty or the platinum points were not sufficiently immersed to form a good contact, or the mercury were to adhere to the points as they were withdrawn, a difference in the intensity of the sound might be heard. The mercury was carefully cleaned every few days, or fresh mercury put in. The platinum points were filed smooth and kept brushed. Strong elastics were attached to each key, so that when the keys were released there was no delay about reacting. If then there were any variations, since there were five sets of keys, it ought to recur every fifth sound; but as a 5-rhythm was always found very difficult, and a 2, 3 and 4-rhythm easy, we have strong ground for believing that any variations except those which were intended were so small as to have no influence upon the rhythmical grouping. We have, then, the testimony of all the subjects that the clicks seemed uniform in intensity.

Subject 2 always heard a uniform series for a time after a change of rate, or at the beginning of a new experiment. His tendency to group was so strong that he could avoid it only by imagining some one pounding in the distance, or some objective thing that was perfectly uniform. Subject 3 did not feel any tendency to group the sounds until after he had tried several suggestions. Subject 9, taking a critical attitude, was inclined to believe for a time that the clicks were all of the same intensity. After a few moments it required an effort, which was like "looking long into the

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[1] AMERICAN JOURNAL OF PSYCHOLOGY, Vol. IV. pp. 534 and 539.

future," to avoid a grouping. "I find no rhythm," he says, "as long as I hold my breath and stick to it." When subject 11 gave close and critical attention to the sound, there was no grouping. In order to get a notion of a *rhythmic* series—one of uniform intensity—subject 12 turned his attention "backward" and saw a series of images to which he was adding one all the time. He throws his attention upon what comes, and studies the nature of the sounds to see if the timbre remains the same. Subject 17 says that when each click was attended to separately, they all appeared to be of the same intensity. He said he experienced no such difficulty in avoiding a rhythm as the statement of Wundt had led him to suppose. Subject 25 could group the sounds, but he was more inclined not to do so. If he suggested a grouping, it did not persist. Subject 27 found it more natural to associate the sound with dripping water. Subject 29 made the series appear uniform when he thought of hammering. Subjects 18 and 30 could not effect any grouping at all. Upon this evidence we may safely rely upon having secured a series of impressions that was uniform for sensation. It is also true that though the rhythmical grouping of a series of uniform sounds is difficult to avoid, this tendency may be restrained within the limits spoken of by Wundt. Our own experience tallies with those above. When the attention is directed to each single impression, and an attempt made to study the timbre, it is possible to restrain the rhythmical grouping of the sounds. But when the series is attended to as a whole, this grouping takes place involuntarily.

The character of the sound employed in the experiments of Dietze differed greatly from that used in these experiments. The click of the telephone is about as simple and instantaneous a sound as it is possible to produce. The plate in the telephone vibrates a very short time. For that reason its chief characteristic is intensity; it does not persist long enough to establish its pitch and timbre. The mind has very little to work upon. It can construct variations only in intensity, for which reason the carrying power is greatly reduced. The sounds can be subordinated with respect to intensity only, and unless great intensive variations can be made, the mind will lose its grasp, and the grouping break up into single impressions. This phenomenon was observed several times, and in particular by subject 15. The sound of the metronome which Deitze employed is full and rich and has greater carrying power. Any experiments upon the carrying power of the mind must take into consideration the character of the sound. Dietze was able, by strong voluntary effort, to carry the grouping much farther than any subject in

this experiment was able to do with the clicks of the telephone. The explanation is to be found partly in a difference between the two sounds and partly in a different method. The subject in these experiments was requested to group the sounds, not by voluntary effort, but only so far as it was found easy and spontaneous. There was no attempt to force the grouping as far as possible, or even to force the grouping at all. It was the spontaneous and involuntary grouping that was studied.

In a study like this, which is purely introspective, the experimenter must rely upon the integrity of his subjects. There is and can be no test of the accuracy or truth of the results, except the uniformity which they show. If, however, each subject is unaware of the object to be obtained by the experiment, and of the opinions of every other subject, and renders his judgment without any interest in the results or without any preconceived notions of the experiment, the judgments are no more subject to error, and have about the same value as judgments in psycho-physical experiments. Certain attitudes, habits, and characteristics of mind do, however, affect results in certain ways which are injurious to the experiment. Some attention was paid to the attitude and method of the subjects in making judgments. A few words in regard to this may not be out of place. There are three classes of psychological subjects. The first includes those persons who yield immediately to any suggestion that is offered. This attitude results, then, from a social practice. In society, people do not wish to antagonize others. They instinctively give assent to any opinion. In an experimental investigation, if the operator will just give the slightest hint of his theory or preference they will add the weight of their opinions. If the operator leads them into giving an opinion which is opposed to his theory, "consistency becomes a jewel;" they stick to their opinion stoutly. If the experiment shows plainly that they are wrong and it is preposterous to hold such a view, they make a compromise with their former position and try to excuse themselves for having been led astray. They remain respectfully silent afterward and avoid, if possible, giving an opinion. If they are forced to make a judgment, they do it tentatively; they are not sure. Of a number of possible views they cannot make up their minds which is the correct one. They generally hair-split until they find out someone's opinion and then agree with that.

The second class of subjects includes those who take a moderately critical attitude. They are concerned in others' opinions in so far only as other opinions suggest different points of view. They give their own opinions when they

have considered all the phases of the experiment that are suggested to them. They are unconcerned about the outcome of the experiment. They are not dogmatic; they might have a different opinion under different circumstances or with further consideration. In the light of the evidence before them, they hold to a certain view.

The third class includes those persons who are excessively critical. They incline always to an opposite view. The experiment is not conducted properly to suit them; they are not in their best mood for judgment. They are sure to take ground against some one's opinion. If they cannot get any clue to others' opinions, they are doggedly silent or quibble, and refuse to answer except they qualify their answers to such an extent that the answer means nothing. This class of subjects is intellectually dishonest. If they are compelled to answer, they indulge in hair-splitting differences between their opinions and those of some others.

When the experimenter is compelled to rely entirely upon the judgment of his subjects, he must study them carefully and use the opinions of certain subjects in so far only as he finds that they harmonize with the general results. It is a fact which every psychologist must understand that certain classes of persons are incapable of introspection. The first class to which we referred are unfitted, because of habits of too free judgment and of always agreeing with others. The third class are rendered unfit for introspection from habits of too free judgment in regard to matters that concern themselves, and from an unnatural bias toward the negative. They are inclined to make too much of their individual opinions. In making out the results, the investigator cannot rely much upon individual opinion. Where there is almost perfect uniformity, the results may be given in tabulated form; but a large space must be given to merely individual opinion.

We have then to inquire first in regard to the certainty of a rhythmical grouping of a series of absolutely uniform sounds. The point does not need argument; the preceding records show how strong is this tendency. Only three out of fifty or more persons tested would agree that it was easier to hear each click separately. In addition to the records given above, several subjects were asked to give a written statement of their impressions of the experiment. In one case definite questions were asked in writing.

(A) "As far as I can recall my impressions at the different occasions on which I listened to the series of sounds from your apparatus, they appeared to me always as a sequence of groups containing the same number of elements. The exceptional cases where the impression was that of a sequence of

single sounds, were those in which the period of the sequence was at its longest. For any given rate there was in general one certain number of elements of which the groups more naturally consisted than any other: but I found, too, that the sequence took on instantly the character of almost any other grouping that was suggested, whether by word or sound. As to the psychological nature of this phenomenon of grouping, it is a difficult matter to give an opinion. I found the effort to determine whether or no there were any recurrent differences of sensation in the sequence a great strain upon the powers of attention. The grouping had in general the appearance of being forced on the mind by the sounds rather than that of being imposed on them by it."

(B) "A series of clicks may be given in such manner that by giving the closest possible attention they seem to be uniform both as to intensity and interval. This degree of tension (of attention) can, however, be maintained for only a few seconds. When the attention is moderate, the clicks tend to fall into rhythmic groups, the number of clicks falling into a group varying with the rate of the clicks. Slower than a certain rate no rhythm is felt. With more rapid rates two clicks form a group, the accent falling on the first and an interval occurring after the second. Faster still, four clicks form a group with accent, primary on the first and secondary on the third, and an interval after the fourth. This seems a very pleasing rhythm to me, more so than any other. A still more rapid rate gives eight in a group. This becomes visualized quite strongly in my case. It is exceedingly difficult for me to hold the series of clicks out of some of these rhythms. They fall into one or the other types (according to rate) almost irresistibly. At some rates I was able to get a 3-rhythm, accented strongly on the first."

(C) "With regular ticks within certain limits, I do not perceive them as distinct separate ticks, but from the first I group. With slower rates, the grouping is two by two, which passes very easily into four, subdivided into two. With faster rates, the tendency is to perceive the grouping into fours, divided into two, or to perceive the grouping into threes. The quicker the rate, the larger the number of ticks entering into the groups up to about six. Below the lower limit, the ticks are first perceived separately with a tendency to fall into twos, this tendency decreasing as the rate decreases. Above the upper limit, the grouping becomes vague and the tendency is to perceive the ticks as separate and individual. In general the grouping can be changed within certain limits."

"The groupings influence one another. There is a tendency to become habituated to a grouping. A grouping heard in one rate is likely to repeat itself in a subsequent rate. It is difficult to be perfectly passive when one knows he is to find a rhythm."

(D) "It seems to me easier to group the clicks unless they are very slow; but I do not find it so difficult to perceive them singly as I should have inferred from Wundt's remarks on Dietze's experiments. Having now tried many times when the grouping was strongly present, subjectively (voluntarily) or objectively, I think I am a little more inclined to discover groupings. It seems to me that I do not lengthen, but rather intensify one or more of the sounds. Perhaps, however, the change is more in quality than in intensity, or perhaps an accompanying impulse of the diaphragm, stress in the mental counting, etc., etc. Possibly, however, I do also lengthen the stressed sound at the same time; but the lengthening is not so clear as the stress. I infer from my experience as a subject that the rates from 1 or 2 per sec., up to 6 or 8 per sec., are best; probably about 4 per sec. being the best. The fast rates are better for groupings by four, the slower for groupings by two. Three-groups, 5-groups and higher groups do not occur spontaneously with me, though 3-groups are not hard to start by counting. Perhaps 2-groups go easiest of all with me. There is a sense of expectation of 'hope deferred' when the rate is too slow — or, at least, a feeling of 'too slow,' like traveling in a slow train, although you have plenty of time.

"This probably increases with the length of the group. The span of the respiratory rhythm is exceeded, and instead of being able to tell off a whole foot of the rhythm with one breath, several breaths intervene between those that mark the accented sounds. With small groups and rapid rates there is a feeling of hurry. The motion is too quick and short. There is none of the repose—the swaying, the grace, the easy fulfillment of expectation that a slower rhythm possesses."

This rhythmical grouping was a series of efforts to attend to the sound. The grouping results from a sequence of acts of attention. When the attention is directed to the sensation, it lays hold upon the first impression with great force and makes it the sole object of consciousness. If this were the only sound, the attention would turn to something else, but as succeeding impressions follow before the first wave of attention has subsided, they are seized upon with less force than the first impression, and are subordinated to it in different degrees according to the strength of the apperceptive act. Subsequent waves of attention follow the same process as long

as the will directs the attention to the phenomenon. The attention accommodates itself to a certain number of impressions, which fall easily within the period of a wave, providing there is no objective difference in the impressions. If there is a regularly recurrent difference, this becomes the signal for a new act of attention, providing only that the span does not exceed or fall much under the normal period of a wave. If this recurrent difference follows at too great intervals, the attention breaks up the span in two portions, the one more emphatic than the other. If it follows at too small intervals, these periods fall together into group, first of two and then of larger numbers. The too great interval is marked by a feeling of suspense, and the too short interval by a straining after something more.

The number of uniform elements which may enter into a member of the sequence is not determined wholly by the time interval which separates them. Previous mental habits and associations influence the number of elements in the members of the sequence. All individuals are more habituated to two and its multiples than they are to three. There are also many associations which will suggest groupings by two and four. All ordinary muscular movements follow a rhythm of two. The associations of four are far more frequent than those of three. For this reason to a large extent, groups of two and four prevail. Several subjects have described this effort of attention in a manner which deserves notice and which shows very well the nature of the act.

Subject 7, speaking of his grouping by eight, says he is not able to "round up" until he comes to eight. There was feeling of completeness about the 8-group with a certain rate. Subject 9 says there is a slight feeling of muscle tension in the ear, sometimes in the back of the scalp. He attends, relaxes, and attends again. There is an innervation of the muscles connected with attention. Subject 12 describes his feeling about the grouping as a tendency "to go back" when he has heard three or four clicks, as the case may be. This is a "mouthful"—a unity, and, when he has one, he seeks to get another. Subject 11 describes his feeling as a series of efforts of attention. He grasps and grasps again. Subject 17 says each group is attended with a feeling of having completed a member of the rhythm. The groups stand out as unities—as wholes—and as each group becomes complete, there is a striving for the next. Subject 21: "I attend now to the series of clicks, then relax and attend again. During the strains of attention, I may grasp three or four clicks. A feeling of relief follows each strain of attention. All the mus-

cles of the body seem to point toward the source of the sound. They alternately contract and relax."

This is the rhythm in the attention to which a reference was made above. The view taken, then, was that only one undivided state of consciousness might arise during each pulse or wave of attention, and that the number of objects which can be grasped in that state must form an organic unity or be presented as a single object—have the appearance of a unit.

A given number of auditory impressions within certain time limits, when presented in such a way that there is a kind of subordination among them with respect either to time, intensity, pitch or quality, or with respect to any two or more of these properties, always stand as a unit in consciousness. They form an organic unity which is the essential condition of a number of impressions entering into a state of consciousness. If such organic unity does not exist and it is possible to make it, the mind imposes such an arrangement upon a given number of the elements that they may enter into a state of consciousness. *The essential conditions of forming such a unity among sounds is a regular temporal sequence within limits which shall be named hereafter, and perfect uniformity in intensity, pitch and quality.* Regular variations within limits with respect to intensity, pitch or quality, or to any two, or to all of these together, will effect a subordination among them sufficient to constitute an organic unity. There is a temporal limit within which these variations must occur in order to form such a unity.

The test of how many auditory impressions might be grouped together was the ease and pleasure which the subject found in doing so. If he were compelled to keep up a constant suggestion of a particular number in order to group the clicks so, noaccount was taken of it. If, after suggesting a grouping, it should persist until some other suggestion was made, the rate was considered favorable for that form of grouping. The subjects have described some groupings as most natural, easy or pleasurable, and others difficult or displeasing. The groupings which were spoken of as natural, easy or pleasurable, are gathered together in the following table, with the time, to determine what rates have been found best adapted to the different forms of grouping.

In the following table are brought together the judgments of all those subjects with whom extensive observations were made. The number of the subject is given in the first column at the left hand, and in the columns to the right are given the rates in thousandths of a second, at which a certain form of grouping was found pleasant and easy. The designations at the top of columns 1, 2, 5, 8, 10 and 13 are sufficiently clear.

The others require further explanation. In column 3 are given those rates at which the subjects found a 2-group more easy, but there was a straining for a larger group, or the 2-groups seemed to group by two. The rate was a little fast for a 2-group, and yet it was not more pleasant to group by four. In the same way certain rates were found at which a 3, 4, 6 or 8-group was easier than any other, but it was a little too fast for simply grouping by these numbers, and hence the groups tended to group by two. This was generally spoken of as the "pendulum-swing movement." Still other rates were found at which a 4, 6 or 8-group was more pleasant, and yet the rate was too slow, and the group tended to divide into two smaller groups. In column 15 are given those rates at which there was no distinct grouping—simply a periodic intensive change in the series. Rates at which there was no appearance of a group are given in column 16.

Multiplying the average rate for each form of grouping by the number of clicks in a group, we get as the length of groups:

Lower limit for no group,	1.581 sec.	Average variation,	.29 sec.
Average length of 2-groups,	1.590 "	" "	.328 "
" " " 3 "	1.380 "	" "	.204 "
" " " 4 "	1.228 "	" "	.068 "
" " " 6 "	1.014 "	" "	.028 "
" " " 8 "	1.160 "	" "	.025 "

The foregoing table shows that the lower limit for the rhythmical grouping of sounds is near 1.58 sec. Some subjects are able at times to group sounds that are separated by this interval, but as a general rule spontaneous grouping has ceased. The records give several instances where the subject has visualized the pendulum with this rate, but he had a feeling that the pendulum reached its full swing before he heard the click. The upper limit at which spontaneous rhythmical grouping ceases cannot be far from .115 sec. Several subjects declared their inability to make definite groups at a rate less than this. Others perceived only a periodic rise and fall in the intensity of the sound; there was no definite grouping.

Between these limits there was some form of rhythmical grouping which depended in a large measure upon the rate. The average of all the rates at which a grouping by two was found easy and natural has been taken and multiplied by two to find the average length in time for the 2-groups. The same has been done for groups of three, four, six and eight. The averages for groups of all forms are found not to differ greatly, when we consider certain facts which influence the length of the group. The average length of 2 and 3-groups is somewhat greater than the average for groups of

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Subject.	No Group.	2-Group.	2-Groups Group by two.	4-Groups tend to Divide into two 2-Groups.	4-Groups.	4-Groups Group by two.	8-Groups tend to Divide into two 4-Groups.	8-Groups.	8-Groups Group by two.	3-Groups.	3-Groups Group by two.	6-Groups tend to Divide into two 3-Groups.	6-Groups.	6-Groups Group by two.	Periodic Intensive Changes.	No Groups.
1	......	1 152 1 140 1 000	......	......	.570 .230 .323	....	......	...	...	.323 .208	.167	......	....	......	......	....
2	......	1.002 .323 .323	.263	.263	.323 .263	....	......	...	....	.208	......	.167	....	......	......	....
3	2 301	.323 .500 1.140	.268 .760 1.140	......	.760 .500 .230	....	......	...	....	.760	.167	......	....	......	......	....
4	1 600	1.072	1 072	.646 .646 .536 .536	.823 .288 .268 .134 .208 .268 .323	.170 .116 .156 .134	.116	....	....	....	......	......	....	......	......	....
5	......	.780 1.440	......	.....	.288 .420 .323 .353	.208	......	.156 .183 .208	....	....	......	......	....	......	......	....
6	1.440 1.660	.300 .780 .353 .780	......	.300	.353 .288	.167 .156 .288 .134	.134	....	....	....	......	......	.156 .156	.137	.156	....
7	1 140	.780	......	......	.300	....	......	....	....	....	......	......	...	......	.156	....
8	1.440	......	......	......	.300	....	......	....	....	....	......	.....	.167 .208	.137	......	.156
9	2. 1.440	.780 .760 .540	.268	......	.300 .134	.134 .268	.156 .166 .116 .116	....	....	....	......	......	....	......	.....	....
10	1.440	.460 .268 .780	......	......	.268 .300 .300	.134 .116	.116	.134	....	.268 .353	.134	......	.156	......	......	....
11	......	1.67	......	......	.268 .500 .250 .268 .323	.268 .167 .263 .115	.137 .115 .156	....	.134	....	......	......	.208	......	.115	....
12	1.660 1.440	1.56 .760	......	......	.156 .300	.156	......	.115 .115	....	....	.156	.156	.115	......	.115	....
13	......	.285 .352 .288 .268	.288	......	.285 .352 .652 .208	.340	.115	....	....	.352 .780 .969	......	......	....	......	......	....
14	......	.780 1.440	......	......	.780 .285	.300	.156 .285	....	....	....	......	......	....	......	......	....
15	......	......	......	......	.300 .268 .134	...	......	.134 .116	.116	....	.268	....	....	......	.116	....
16	1.660 1.720	.288 .323	......	......	.156 .263 .167	.115	......	....	....	...	......	......	....	......	......	....
17	1.615	.789 .965 .969 .849 .268	.352	.624 .789	.352 .307 .307 .500	.167 .208	......	.167	....	.624 .501	.167 .789	......	.192 .208	......	......	....
19	......	......	......	......	.268	....	......	....	....	....	......	......	....	......	......	....
20	......	......	......	......	.268	....	......	....	....	....	......	.....	....	......	......	....
22	.780	......	......	......	.300 .268	....	......	....	..	....	......	......	....	......	......	.156
23	1.938	1.672 .969 .700 .969 1.072	......	.536	.208 .323 .323 .208 .208 .268 .536	.167 .170	.134	.167 .116 .134	.134 .116	.323 .323	......	......	.156 .156	.137	.134 .115	....
Average	1.581	.795	.526	.542	.307	.188	.134	.145	.125	.460	.149	.161	.169	.137	.127	
Average Variation	.29	.328	.204		.068	.043		.025	.009	.204	.028		.028			

six and eight. The explanation for this is to be sought in the fact that persons are more accustomed to rhythms of two and four than to the longer rhythms.

The average variation for 2 and 3-groups is greater than for groups of four, six and eight. The associations with the 2-rhythm are far greater than with any other, and these associations tend to suggest the 2-group where it would not otherwise occur spontaneously. Long experience with clocks that vary greatly in their rates of ticking has much to do with the wide limits within which the 2-rhythm is possible. The 3-group is a more rare form of grouping, and only a few subjects succeeded in suggesting it easily. For that reason it is not surprising that the average time of the 3-group should differ greatly from the others. Then the power to carry one or two impressions in the mind is greater, and they can be held longer. The actual span for two clicks in a given time is only a little more than half the span for eight clicks in the same time. In the first case almost half the interval is a pause between the groups, and in the second the pause takes up less than one-eighth of the interval.

There are several facts, as the records have shown, that tend to make the length of groups vary. Several subjects were predisposed to groupings by four. This number has had a peculiar charm for one from early boyhood. It was his number in school, and ever since, objects that were grouped by four, or that could be grouped by four, have had an especial attraction for him. Four impressions, of whatever sort, always arrest his attention. For this reason he attempted to group all rates by four, even though it required strong effort to do so. With two exceptions, all subjects had the prevailing tendency to group by four. A second fact, which influenced probably the grouping to some extent, was that when a subject found it easy to group a given rate by four he became somewhat habituated to a 4-grouping, and was inclined to group the succeeding rates by four, unless they differed greatly. If a very slow rate followed a faster one, which had been grouped by three or four, the subject tended to imagine intermediate clicks between the actual clicks, and still to group by three or four, as the case might be. (See the records of subjects 1, 6, 12, 13 and 17.) Taking all the forms of grouping together, the average time is taken to indicate the normal period of a wave of the attention which does not exceed greatly one second. A spontaneous effort of the attention, or with Wundt a wave of apperception, endures about a second or more. We do not, however, hold that there is an absolute psychical constant, even for the individual. No other fact is more certain than that the condition of the

subject, as regards fatigue and previous engagement, has much to do with the rate at which a certain group is found pleasant and agreeable. (See the records of subjects 1 and 3.)

Before leaving the subject, let us call attention to the averages for groupings that are intermediate between two and four, four and eight, and three and six. The averages for the rates at which these groups were observed lie between the average rates for the groups between which they stand.

A further method of testing the normal length of a spontaneous effort of attention was sought in this way. An accented sound every sixth or eighth was introduced into the series, and a number of different rates were tried, until one was found at which the group seemed most pleasing and natural. If the rate was too slow for easy grouping, the subject perceived a feeling of suspense. A slower rate still, caused the group to divide into two parts, or at least the subject felt a tendency to divide the group. A still slower rate generally caused the long group to disappear entirely, giving place to a number of small groups which were equal to the long one. If the rate were too fast for easy grouping by six or eight, the groups tended to group by two with a kind of pendulum-swing or wave-like movement. Before trying a subject upon an accented series of six or eight, he was given a number of rates with uniform clicks, beginning with a slow rate. The purpose was to determine to how great an extent the form of grouping changed with different rates, when they were given in close succession. The results of the experiment with a series of uniform rates are given in the first part of the following table. The results of the experiment when every sixth click was accented are given in the second part, and when every eighth click was accented, in the third part:

Unaccented Series, Part I.

Subject 7.	.323 (.268) 4-group. Tends slightly to 8-group.	.263 4-group. Strongly tends to 8.	.208 8-group. Pleasant.	.167 Groups not separated. Confused feeling.	.137 More confused feeling. Accented double 6-group.
Subject 16.	2-group.	4-group.		6-group. Not so easy as with the following rate	6-group. Groups by two.
Subject 3.	3-group.	Double 3-group.		3-groups. Groups by two.	
Subject 4.	.268 4-group. Pleasant.	.208	.17 4-group. Confused.	.134 4-group.	.116 4-group. Groups by two.
Subject 10.	4-group. Pleasant.		.156 6-group. Pleasant.	8-group. Pleasant.	
Subject 13.	2-group. Groups rise and fall.	4-group.	4-group. Groups rise and fall by two.		8-group. Groups by two.
Subject 16.	2 or 4-group.	2 or 4-group.	3 or 4-group.		8-group. Divides into two 4-groups.
Subject 9.	4-group. Tends slightly to double 4-group.			4-group. Strongly towards 8.	8-group. Divides into two 4-groups.
Subject 17.				8-group. Illusive.	8-group.
Subject 5.	.78 2-group.	.353 4-group.	Wavers between 4 and 8-group.	.183 8-group.	.156 8-group.

Accented 6-Group, Part II.

	.323	.263	.208	.167	.137
Subject 6.	4-group. In spite of accent.	6-group. Suspense tends to 3-group.	6-group. Difficult.	6-group. Pleasant.	6-group. Groups by two.
Subject 11.		6-group. Tends to a 4-group.		6-group. Pleasant.	6-group. Groups by two.
Subject 16.	6-group. Two 3-groups. Span disagreeably long.			6-group. Divides into two 3-groups.	6-group. Pleasant. Pendulum-swing movement.

ACCENTED 8-GROUPS, PART III.

Subject 4.	.268 4-group.	.208	.17 4-group.	.134 Two 4-groups.	.116 8-group.
Subject 10.	4-group.		8-group. Requires effort.	8-group. Not animating.	8-group. Harmonious.
Subject 11.		4-group. Accents disturbing.	8-group. Accents disturbing.	8-group. Not pleasant.	8-group. Pleasant.
Subject 13.		8-group. Not complete. Two 4-groups.	8-group. Divides into two 4-groups.	8-group. Pleasant.	8-group. Groups by two.
Subject 16.	8-group. Really 4-groups. Great suspense for 8-group.	8-group. Distasteful feeling of suspense.		8-group. Divides into two 4-groups. Span too long.	8-group. Pleasant.

With the unaccented series, the 6-group was found natural twice near the rate .167 sec. When every sixth sound was accented, the most pleasant rate for the 6-group was .167 sec. At the rate .137, the 6-groups group by two. At the rate .208 sec., they were difficult to grasp. At slower rates, there was a feeling of suspense, or the group tended to divide into two 3-groups, or the subject was more inclined to group by four in spite of the accent. According to this, the 6-group is found most natural and pleasant at the rate .167 sec. By multiplying this by six, we will get as the time limit for the 6-group 1.002 sec.

With uniform series, the 8-group was found most natural and pleasant, once at the rate .208 sec., once at the rate .134 sec. and twice at the rate .116. When every eighth was accented, the 8-group was found most pleasant at the rates .134 and .116 sec. The average rate for all is .130 sec., which, when multiplied by eight, gives 1.04 sec., the time limit for the 8-group. The difference between this and the time for the 6-group is very small, and at the same time they agree very well with the times for the same groups in the preceding table. The general fact of certain rates being better adapted to certain forms of grouping is pretty well established. This adaptation of a particular form of grouping to a certain rate depends upon the fact that the length of the group corresponds to the normal period of a wave of attention. The lack of adaptation results from cutting short the normal wave. For a fuller account of the different states of feeling arising

with different rates for a certain group, the reader is referred to the records of the experiments upon subjects 10, 11, 13 and 16.

The conscious state accompanying each wave of attention grasps together or unifies all the impressions that fall within the temporal period of a wave. As the result of a series of attentive efforts, a series of auditory impressions takes the form of a sequence of groups. This rhythmical grouping is due to the unifying activity of the mind; it is an attempt to conceive a series of sounds in a simpler form. When the mind acts upon a continuous series of auditory impressions, it groups all the impressions that fall within the period of a wave of attention, and conceives them as a single impression or a unity. Each succeeding wave groups a like number, so that the series is conceived in the form of groups. If the single impressions are separated by a greater time interval than the normal period of a wave of attention, each impression stands alone as the sole object of consciousness. But what becomes of the series when the rate is too fast for rhythmical grouping? A partial answer is to be found in the fact that the clicks show a regular periodic rise and fall in intensity. There was no separation among the groups; no definite number of impressions constituted the group. The view to which least objection can be offered, but which is unsupported at the same time by any positive evidence, is that when the sounds become too rapid to find expression in muscular contractions of any kind, they can be no longer separated from one another as simple impressions.

The most rapid rate[1] of voluntary control is about ten per second. This periodic rise and fall in the intensity of the clicks simply marks the waxing and waning of the attention. The changing intensity of the sounds indicates the changing degrees of clearness in the conscious state. If the clicks are separated by more than one-tenth of a second, the groups are separated by an interval; at least, there is the feeling of an interval. Below this limit of one-tenth of a second, the clicks preserve their individual character. They do not fall sufficiently near together to appear continuous. They preserve their temporal succession, and as before appear in different strengths according to the degree of clearness in the conscious activity. The conscious state, which seems to ride upon the crest of the wave—that is, appear when the attentive effort is at its strongest—fades gradually and conceives the last elements in the group with less clearness than the first, and with the coming of a new wave of attention, the first impression is laid

[1] "Some Influences which Affect the Rapidity of Voluntary Movements." F. B. Dresslar. AM. JOUR. OF PSYCHOL. Vol. 4, p. 516.

hold upon with great force, and appears stronger in contrast with the last in the preceding group.

This rhythm in the attention, and hence in conscious activity, finds its counterpart in the activity of the nerve cell, which we have seen reason for believing was a series of explosions—an alternation of periods of activity and periods of repose.

The subject invites speculation, but we forbear except to offer the further supposition that with rates slower than ten per second, the interval or pause between the rhythmical groups marks a period of perfect quietude in the cell. When the rate reaches ten a second or more, there may still be a period of absolute inactivity, but no less interval than a tenth of a second can cause a real break in the conscious state or no less interval becomes an "object of consciousness." The change from one state of consciousness to another is represented by the reversal of a muscular movement. If between two impressions there is not sufficient time or time equal to the reversal of motion in a member, there is no consciousness of an interval between the impressions. The thought of the interval is a deduction and not a sensation or conscious fact —a fact revealed by the immediate conscious state itself. The conscious state disappears when the activity in the cell ceases; and when the will directs the attention to the series of impressions, the conscious state tends to disappear when it has effected all the subordinations that are possible among the impressions that fall easily within the normal period of a wave of attention.

Another phenomenon, which was observed by several subjects and by the experimenter at different times, was the apparent slowing up of the rate. The feeling was one of extreme suspense, and was described as "awful" and "dreadful." There was no apparent regularity with which the slowing up occurred and no definite time that the feeling lasted. The only fact which was observed concerning it was when the attention was diverted, the feeling disappeared. Several suppositions occur to us as explanations, but none of them seems to be completely satisfactory. It appears to be more in the nature of fatigue, but it is not clear why the impression should seem to be separated by longer intervals. The general fact, however, of time passing more slowly, when one is suffering from fatigue, has been observed frequently. A more probable supposition is that it indicates a kind of rhythm in the voluntary effort which directs the attention to the source of the sound.

We have now to ask what is the inherent nature of a rhythmical group, or what is meant by a unity among

a number of auditory impressions. What relation must the impressions bear to one another that they may be grouped together or grasped by a single act of apperception? How may a number of impressions become the object of a single state of consciousness? With Plato, we ask how the many become the one, or with Kant, how the mind makes a unity out of a manifold. Upon the basis of this study, we can hope to answer the question with regard to auditory impressions in a sequence. The question has already been answered for simultaneous sounds—musical tones—in the laws of harmony. The general principle as laid down in the treatment of poetry was that by coördinating and subordinating the elements to one another, unities were effected among them. The same principle holds good here.

From the nature of the apparatus, only changes in the intensity of the clicks could be effected. For this reason the subordinations and coördinations among the sounds must be accomplished through different intensities. Two methods for determining the relations of the sounds in a group with respect to their intensities were employed. By the first each subject was asked how he effected a grouping in a series of sounds which were of uniform intensity, and, if by accent, what sounds in the groups were accented. By the second method, the subject was given a series of sets of sounds of different intensities, which recurred always in the same order, and he was asked to point out where the series was grouped —the position of the strong and weak sounds in the group. In this way we were able to determine what was the most natural order in which the different intensities occurred in the group.

By the first method, it was determined that:

The first sound in the 2-group was accented. It was possible by objective suggestion of tapping, or counting, or by voluntary effort, to accent the last sound, but no subject would agree that this was the natural accent.

The first sound in the 3-group was strongly accented and the second slightly. Occasionally a subject found it easier to accent the second more strongly than the first, but this did not seem to be the natural way of accenting the group. It was possible by voluntary effort, or objective suggestion, to change the position of the accent. Very few subjects found it easy to group by three, and it usually required a strong suggestion to start the group.

The 4-group was very generally accented upon the first and third sounds; the first was stronger than the third. There was, however, some difference of opinion. Several subjects found it easy and natural to accent the second and fourth, and

subject 15 was more inclined to this form of accent than to the other. Sometimes there was only a single click accented, and this was very generally the first. The accents could be changed voluntarily. The reader is referred to the records of subjects 1, 2, 6, 7, 9, 10, 11, 13, 15, 16, 17, 20.

Most subjects preferred a grouping by four to one by three. When the attempt was made to suggest a 3-group by counting three, they felt an over-powering tendency to count one or three a second time. Thus: 1, 2, 3, 1—1, 2, 3, 1—1, 2, 3, 1 —or 1, 2, 3, 3 — 1, 2, 3, 3 — 1, 2, 3, 3. The former was the more common. Subjects 1, 4, 7, 11, 12, 13, 15, 17 and 20 mentioned this phenomenon.

The 5-group was very difficult to suggest and maintain. Most subjects declared their inability to get such a grouping. Subject 11 said that an extra click would attach itself to the group and "pull it over" to a 6-group. Subject 17 mentioned a similar phenomenon. In counting a 5-group, it was found easy to emphasize the first and third or the first and the fourth. This gave to the 5-group the appearance of being compounded of a 2-group and a 3-group. Subjects 10, 11, 12, 15, 16 and 17 make observations on their attempts to suggest a 5-group.

The 6 and 8-groups were generally compounded of smaller groups of two, three or four. The 6-group was composed of two 3-groups or sometimes three 2-groups. The first group in the 6-group was more emphatic or was accented. The 8-group was composed of two 4-groups or sometimes four 2-groups. Subject 13 thought that the intensities of the sounds in the 8-group decreased from the beginning to the end.

Higher grouping of these groups was possible to some extent. The most common form was to group by two. This was spoken of as the pendulum-swing movement. In this case, the first group was always accented. Subjects 1, 10, 12, 13, 15 and 16 make observations upon their attempts to group 2 and 3-groups. The record of subject 16 is especially important. Several were unable to group 4-groups beyond two, on account of their inability to keep the accents clear. In general all subjects made a kind of interval between the groups. In 6 and 8-groups, which were compounded, a short interval followed each smaller group and a longer interval followed the whole group of six or eight.

Various methods of suggesting a grouping were employed. The most frequent method was by counting or beating time with the fingers. Subject 17 says: "Subjective counting is most effective, or this assisted by respiratory stresses and probably other muscular movements." The associations

which the sound brought up, very frequently suggested a form of grouping. The clock (various kinds), pendulum, locomotive, conical pendulum and revolving wheel, making a certain number of sounds during a revolution, are most frequently mentioned as influencing the form of grouping. The operator frequently directed the attention of the subjects to respiration, or asked them to feel the pulse. Most of the subjects incline to the view that respiration accommodated itself to the form of grouping that was found most natural with the rate to which they were listening. Inhalation and exhalation each lasted during the time of a 4-group. In this way a kind of higher grouping was accomplished, for the clicks heard during inspiration were more intense. When the rate was slow both inspiration and expiration were accommodated to the time of one click.

With fast rates, the pulse acted as a suggestion. All the clicks falling between two heart-beats were grouped together, the click coming nearest in time to the heart-beat being accented. Subjects 2, 4, 9, 10, 11, 13, 15, 17 and 25 make observations upon this subject.

When the subjects were allowed to hear the sound of the chronograph, which was distinctly rhythmical, no other grouping was possible. The reader is referred to the records of subjects 2, 3, 9, 11, 16, 19 and 23.

This general conclusion seems to be warranted: In the presence of any fixed rhythm within limits, or of objective suggestion, the series was grouped according to the suggestion, and it was found difficult, if not impossible, to suggest any other grouping. The grouping would follow the stronger suggestion.

Certain rates were more favorable than others for voluntary changes of the forms of grouping. Subjects 4, 6, 13 and 15 mention these rates respectively as especially favorable for voluntary changes: .323 sec., .353 sec. and .268 sec. Subjects 1, 2 and 16 thought that the grouping changed easily when they were fatigued. When a very weak accent was introduced every third in the series, subjects 4 and 13 did not detect the accent, but grouped the series by three, and were unable to suggest any other form of grouping; but they could not tell why the series grouped this way. Subjects 6, 9, 11, 12, 13, 15, 16 and 17 make observations upon easy changes of the form of grouping.

The second method of determining the nature of rhythmical groups was to give the subject a series which was composed of a regularly recurrent set of sounds of different intensities. Sets of two, three and four different intensities in groups of two, three, four and five were studied. Very few observa-

tions were made upon 5-groups. To make a graphic representation of such series of sounds, let A, B, C and D represent the four intensities of sound, A the strongest, and D the weakest. By using only two intensities (A B) it is possible to form the following series of sounds:

2-groups.	A B A B A B A B	(1)
3-groups.	A B B A B B A B B	(2)
	A A B A A B A A B	(3)
4-groups.	A B B B A B B B	(4)
	A A B B A A B B	(5)
	A A A B A A A B	(6)

Of 5-groups, these only were tried:

A B B B B A B B B B	(7)
A B A B B A B A B B	(8)
A A B A B A A B A B	(9)

The question was to determine where the mind most naturally made the division into rhythmical groups. The first series might divide in two ways, thus: A B—A B, or B A—B A. The second in three: A B B—A B B, or B A B—B A B, or B B A—B B.A. Details regarding the others are unnecessary. Of series composed of three intensities, the following out of all the possible forms were thought to be characteristic, and were tried:

3-groups.	A B C A B C A B C
	A C B A C B A C B
4-groups.	A C B C A C B C A C B C

Of series of four intensities, the following out of the many possible forms were tried:

4-groups.	A B C D A B C D
	A D C B A D C B

In the following table are given the rhythmical groups which each subject made of the series upon which he was tried. At the top of the table, in each column, are letters which indicate the order in which the different intensities recurred in the various series. The number of each subject is given in the left-hand column. If a subject has given a stronger intensity to a click than it actually possessed (said that a B intensity was equal to an A, or a C to a B), it is printed in full-faced type. Where a subject has remarked upon a longer interval, either following or preceding the strongest sound, this is indicated by placing a dash either before or after the strong sound:

No. of Subject.	3-Group. Time, .323 sec.				4-Group. Time, .268 sec.						5-Group. Time, .3 sec.		
	Two Intensities.		Three Intensities.		Two Intensities.			Three Intensities.	Four Intensities.		Two Intensities.		
	A B B	A A B	A B C	A C B	A B B B	A A B B	A A A B	A C B C	A B C D	A D C B	A B B B B	A B A B B	A A B A B
1	A B B		A B C	B A C							A B B B B		
2	A B B				B A B B	A A B B	B A A A		D A B C	D C B A	A B B B B	A B A B B	
3					A B B B	A A B B	A A A B	-A C B C	A B C D		A B B B B	A B A B B	
4	A B B		A B C	B A C									
5											A B B B B	A B A B B	
6	A B B		A B C	B A C	A B B B	B A A B	A A A B	B C A C A C B C	A B C D and A B C D	C B A D			
7	A B B		A B C	C B A				A C B C					
9					A B B B-	A A B B-	A A A B-	A C B C-	A B C D-	B A D C- C B A D- B A D C			
10	A B B-	A- A B-	A B C-	B A C-	A B B B-		A A A B-		A B C D-	C B A D		A B B A B	
11	A B B-	A A B-	A B C-	B A C- A C B-	A B B B-	A A B B-	A A A B-		A B C D-	A D C B-	B B B A B	A B A B B	A A B A B
12												A B A B B	
13	A B B		A B C	B A C									
14					A B B B-	A A B B-	A A A B- B A A A	A C B C-	A B C D-	C B A D-			
15	A- B B-		A- B C-	B A- C- A- C B-				A C B C			A B B B B		
17	A B B B A B		A B C	B A C A C B	A B B B	A A B B	A A A B	A C B C- B C A C	A B C D-	C B A D			
26	A- B B		C A- B A- B C	B A- C									
28	A B B	A A B	A B C-	B A C-	A B B B- B B A B	A A B B	A A A B	A- C B C B C A C	A B C D	C B A- D	A B B B B	A B A B B	A A B A B

At the bottom of each column is given the form of group which is generally made when the series is formed in the way indicated by the letters at the top of the column. Two factors seem to operate in determining where the series shall be divided into groups. The group must begin either with a very intense sound or close with a very weak one. The subject strives either to put all the strong sounds as near the beginning as possible, or all the weak ones as near the close as possible. There are three cases where these principles are brought into strong conflict. The first is where the series is composed of three intensities, in the order of A C B or C B A. Either the strongest cannot come first, or the weakest last. The weakest generally comes last and the strongest second; the second being the position of the secondary accent in a musical rhythm. The other form which is common and sometimes preferred, places the strongest first and the weakest second. This does violence to both the weakest and middle intensities, by placing an unaccented sound in a position that requires an accent, and an accented sound in a place where an accent does not occur. A second case is where the series is composed of four different intensities in the order of A D C B or D C B A. The strife would be greater here than in the first case, if it were not for the fact that the third position may frequently receive the sound of the greatest intensity. The most common form is to place the weakest sound last, and the strongest in the third place. This of course leaves the first place occupied by an unaccented sound, though this sound is stronger than the last. Subject 9 makes the strength of the first equal to that of the second, and thus harmonizes the group somewhat with the 4-group, which is formed of uniform sounds. The third case is where the series is formed of a sequence of 4-groups of three different intensities, thus: A C B C. There is really no strife here, except that the strongest sound often appears in the third place. There are some irregularities, but none sufficient to require special notice. The general principle just laid down is well illustrated in the last two forms of the 5-group, when composed of two intensities of sound.

When two or more strong sounds, standing together, are followed by a weaker sound, the sound which is followed immediately by a weaker one appears stronger in contrast with the following weaker sound than the preceding, which is actually of equal strength. This will be observed in every case with 4-groups composed thus: A A A B. And in one case, with the 3-group composed thus: A A B. The third sound in the 4-group and the second sound in the 3-group appear to be stronger than the preceding sound. A

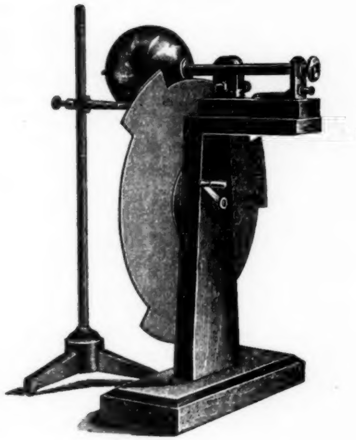
further fact to which attention is called, is the long interval which appears between the groups. The pause seemed to be due to the fact that a long interval generally preceded the accented sound. At the same time some subjects, especially 10 and 15, make a short interval after the strongest sound. To most subjects, the strongest sound seemed longer than the rest. With some this was more apparent than with others. Subjects 1, 3, 4, 10, 11, 13, 14, 15, 24, 27 and 28 either confound the accented click with a longer interval, or make the louder click seem longer than the others. Subject 11 speaks of the strongest sound spreading itself over the rest. It is possible by voluntary effort to avoid the illusion of a longer interval, either preceding or following the accented sound, but ordinarily it was very clear. When the strength of all the sounds in the series was increased, the rate seemed slower. Subject 27, especially, makes this observation. When these accented 3 and 4 groups were given at a fast rate (.134 sec.), the separate clicks seemed to fuse into a single impression, which grouped generally by four.

The different intensities of sound bore no special relation to one another; the strongest was clearly discernible from the second, and the second from the third, and so on. When in a series of impressions of the third (C) intensity, the strongest (A) was introduced every fifth, it seemed to appear as an extraneous sound which would not group with the others. (See records of subjects 9 and 11). It appeared from several other records also that sounds differing greatly in intensity would not easily group together. When a very weak accent was placed upon every third sound, subjects 4, 13 and others did not discover the accent; they expressed their inability to group the series in any other way, but could not understand the reason. Subjects 13, 16 and 17 expressed the opinion that strong accents were disagreeable; they preferred their own accents to real accents of any strength. Real accents did not seem to form so harmonious a group as did the accents which the subjects put in themselves.

As a further investigation into the nature of rhythmical groups, especially with reference to poetical rhythms, it was proposed to employ sounds of which the length or endurance might be varied. The click of the telephone is almost instantaneous. The disk probably makes a very few vibrations. We are indebted to Dr. E. C. Sanford for devising and constructing an apparatus, which served the purpose admirably in some ways. The principle involved in this apparatus was simply interrupting the sound of an electric tuning fork, which was placed before the opening to one of Helmholtz's resonators. When a card is placed over the

opening into the resonator, which is near a tuning fork of the same pitch, the sound of the fork is rendered almost inaudible. Regular interruptions result in a series of uniform sounds and silences.

FIGURE IV.[1]



For this experiment were required an electric tuning fork and a set of disks with notches cut in the circumference. The resonater rested horizontally, supported by a stative near the edge of a small table, upon which the tuning fork was placed. The fork and the resonator were placed at the same height, with just enough space (about half an inch) between the end of the fork and the opening of the resonator to allow a pasteboard disk to pass without interference. This disk was about twenty inches in diameter, and placed at just the proper height to cover up the opening into the resonator. Notches were cut in the circumference of the disk in such a way that when it was revolved the opening into the resonator was now closed and now open. With a regular revolution of the disk, and with notches of an equal number of degrees, and equal spaces, a series of sounds, uniform in length, pitch and intensity, would be produced. To get sounds of different lengths, some notches were made to cover a greater number of degrees of the circumference than others.

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[1]This represents the apparatus as it has since been perfected by Dr. Sanford.

The number of degrees in some cases was twice that of others. By cutting the notches upon the arc of a circle, and at just a sufficient depth to cover a part of the opening of the resonator, it was possible to decrease the strength of the resonance, and thus get a sound of less intensity. This gave the effect of an accent upon certain sounds by weakening others.

The following are the forms of disks that were thought to be characteristic. Just enough space was left between the notches to cause a silence in the sound of the fork. The spaces were always of the same number of degrees in a given disk. Notches were cut in the circumferences of the disks as follows:

1. Two notches, each of 150 degrees. One accented.
2. One notch, 200 degrees, and one, 100 degrees.
3. One notch, 200 degrees—accented—and one, 100 degrees.
4. Three notches, each of 100 degrees.
5. Three notches, each of 66 degrees. The spaces of 40 degrees.
6. Three notches, each of 100 degrees. One accented.
7. One notch, 120 degrees, and two, each of 60 degrees.
8. One notch, 120 degrees—accented—and two, each of 60.
9. Four notches, each of 60 degrees. Strong accent upon the first, and weak upon the third.

The question was to determine where the rhythmical groups began, with the long or the short sounds. As the pause between the successive sounds was the same length, it is a matter of interest to determine what effect the rhythmical group had upon the pause coming after the sound with which the group closed.

The results of the experiments with the different series of sounds produced by the disks, as described above, are given in the following table. A long sound is indicated by a capital letter, and a short one by a small letter. In disk 9 the accented sounds, which were of different intensities, are represented, the stronger by a bold faced A, and the weaker by a bold-faced B. An accented sound is given in full-faced type. In turning the disk, the operator sought to keep a uniform speed at a moderate rate—about one turn to the second:

	2-Groups.			3-Groups.					4-Groups.
	1 A A	2 A a	3 A a	4 A A A	5 A A A	6 A A A	7 A a a	8 A a a	9 A A B A
1		a A	a A-	A A A A A A A	A A A	A A A-	a a A	a a A	
3	A A A A	A a A a		A A A A A A A		AAAA	A a a a a A	a a A	A A B A
4		a A	a A	A A A A A A A	A A A		a a A		B A A A
7			a A	A A A A	A A A		a a A	a a A	
10		a A		A A A A	A A A		a a A		B A A A
11	A A A A A A	A a	A a	A A A A A A A	A A A	A A A	A a a	A a a	A A B A
15	A A		a A	A A A	A A -A		a a A	a a A	A B A A
17	A A	a A a A a A	a A	A A A A A A A	A A A			a a A	
18		a A		No group			a a A		
27		a A	a A	A A A			a a A		
28	A A	a A	a A	A A A A	A A A	A A A	a a A	a a A	A A B A
Groups prefer'd.	A A	a A or a A	a A	4-group or 3-group	A A A		a a A	a a A	A A B A

Several facts are to be observed in this table. First, a series of sounds of uniform length and intensity may be grouped by two, three or four. With disk No. 4, while the most common form of grouping was by three or four, by turning very slowly it was possible to group by two, or by turning faster to group by six or eight. With No. 1 it was easy to group by two or four by turning slower or faster. When disk No. 9 was turned at a slow rate, the sounds were grouped by two, at a faster rate by four, and at a still faster rate the 4-groups were grouped by two or by four.

Second, a more intense sound occurring regularly, imposes a grouping according to the number of sounds between the accents. The accented sound comes first in the 2 and 3-groups, and in the 4-group the first and third receive accents. The first is more strongly accented than the third.

Third, a longer sound occurring regularly in the series, imposes a grouping according to the number of sounds between the longer ones. The long sound, as a rule, is the last in the group, and is frequently accented. It was possible for most subjects to change the place of the long sound to the first of the group, but with the exception of subject 11, it was difficult to keep it at the beginning of the group. Most subjects remarked upon the long interval or pause which seemed to follow the long sound, and for this reason it was found difficult to make the close of the group come at any other place. When the attempt was made to begin the group with the long sound, the preceding group would not seem to separate from the following; the two would run together and become indistinguishable. In the telephone experiments, when a subject attempted to suggest a 3-group, which was accented upon the third by counting one, two, *three*, emphasizing three, it required the closest attention to make the group close with three, for the emphatic three would begin the group thus: *Three*, one, two, etc.

Although it was impossible to control the rate, faster rates than common caused these groups to group by two or four.

The accented long sound frequently appeared more prolonged than the unaccented sound of the same length; the accent had the effect both to increase the length of sound and of the interval which followed.

When the short sound in disk No. 2 and the last short sound in disk No. 7 were accented, the accented sound always came first and the long sound last. It was more difficult with this arrangement to place the long sound first and the accented last, than before.

The results of this experiment confirm in part the results of previous experiments concerning the nature of rhythmical groups. First, the accented sounds occupy the first place in the group. Second, the weaker accent comes upon the third sound in the 4-group. Fast rates with accented groups caused them to fall into higher groups, first of two, and then of three or four.

We come now to the consideration of the nature of the rhythmical group. The general principle is this: In a series of auditory impressions, any regularly recurrent impression which is different from the rest, subordinates the other impressions to it in such a way that they fall together in groups. If the recurrent difference is one of intensity, the strongest impression comes first in the group and the weaker ones after. If the recurrent difference is one of duration, the longest impression comes last. These rules of course hold good only within the limits spoken of above. When the impressions are uniform in length and intensity, the mind

enforces a grouping by giving fictitious values to the impressions, generally with respect to intensity, but sometimes with respect to duration. At the rate .795 sec., the mind intensifies every other sound, so that the series is grouped by two. The second sound in the group is subordinated to the first. At the rate of .460 sec., the mind finds it easy to group a series of auditory impressions by three, by intensifying the first greatly and the second slightly, so that the second is subordinated to the first and the third to the second. More than three degrees of intensity do not appear together in the order of their intensities in a series. In grouping by four, which takes place generally at the rate .307 sec., the mind accents the first strongly and the third slightly. The second and fourth impressions are generally of the same intensity. If there is any difference in intensity, the second is stronger than the fourth, but it is always less than the third or the first. It would appear from this that the 4-group is compounded of two 2-groups, or it may perhaps arise, as Hauptmann says in his "Natur der Harmonik und Rythmik," from a combination of two 3-groups. However this may be, the 4-group does appear as a harmonious and organic unity in itself. Given, then, a series of impressions which is made up of three or four intensities recurring as a sequence of fours, the mind divides the series into rhythmical groups, whatever may be the arrangement of the intensities in the sequence of four, so that the impressions are subordinated to one another as nearly as possible from the beginning to the end. The effort is always made to subordinate the last impressions to the first. The same holds good for series which are made up of sequences of two or three. In a sequence of twos, only two impressions can recur; the stronger is always first in the group. In a sequence of threes, the groups may contain two or three different intensities, but the mind always divides the series in such a way that either the strongest comes first or the weakest last.

When the series is composed of impressions different in duration (the longer impression twice the length of the shorter), recurring in a sequence of twos, the mind groups the series by two, placing the longer impression last, and at the same time gives to it frequently a greater intensity. When the series is composed of a sequence of threes, one long and two short, the mind groups the series by three, placing the longer sound last, and at the same time giving to it also frequently a greater intensity. The order of subordination is here reversed. The more important element in the group comes last. For this fact we can offer no explanation upon purely psychological grounds. The fact, however, is interesting for its connection with poetry. Although, as we have seen,

English poetry in its early history contained feet accented upon the first syllable, the most common foot in modern poetry is accented upon the last syllable. What formerly was the beginning of the foot is now the end. In the experimental study with long and short sounds—these correspond to syllables—all the subjects found great difficulty in not making a pause after the long sound, which compelled them to begin the group with the short sound. It was impossible to avoid this pause or to make another after the short sound equal to it, although the interval in every case was the same. Upon this basis and other facts mentioned above, we are able to base our answer to the question whether there is a foot-division in English poetry. Although the long and short syllables do not stand in the absolute relation of two to one, yet the syllables do differ in length and in intensity of accent, and for that reason they tend to fall together in groups. The accented syllables, like the accented sound, will seem to be longer than the unaccented, and in uttering them the speaker will prolong them still farther. Series of syllables, then, which are arranged with reference to the regular recurrence of the accented syllables will fall into groups, and since the accented syllables are longer than the unaccented, a pause will be felt after the long syllable. To use the Latin terminology, the most natural foot must be either iambic or anapæstic. This, however, seems to be due largely to modern ways of utterance. In order for a word to be intelligible, it must be distinctly and carefully enunciated. In the early history of poetry, it was always recited in highly emotional states; words were not articulated, they were shouted. The line of poetry was little more than a series of strong and weak sounds, which, we can argue upon the basis of our experiments, would be grouped with the strongest first and the weakest last. In the change from the merely emotional shout to articulated utterance, the character of the foot changed from one which was accented upon the first to one which was accented upon the last.

We come now to the subject of muscular movements and their relation to rhythms. Most subjects felt themselves impelled by an irresistible force to make muscular movements of some sort accompanying the rhythms. If they attempted to restrain these movements in one muscle, they were very likely to appear somewhere else. Wundt[1] says that the intensive clang change has its nearest pattern in the sensation of motion. A corresponding rhythmical series of motions associates itself in dancing, marching and beating

[1]Physiologische Psychologie, Vol. II. p. 73.

time, with almost irresistible force to the changes of strength in the clang.

The most common forms of muscular movement were beating time with the foot, nodding the head, or swaying the body. Subjects 3, 10 and 17 accompanied the rhythmical grouping by muscular contraction of the diaphragm and chest, and it was exceedingly difficult to restrain them. Other subjects counted inaudibly or made the proper muscular adjustments for counting. Slight or nascent muscular contractions were felt in the root of the tongue or larynx. Most subjects were unconscious of their muscular movements until their attention was called to them, and subject 15 never became conscious of the rhythmical contractions in the eyelids. When he was asked to restrain all muscular movements, he found great difficulty in maintaining the rhythmical grouping. This fact was remarked upon by other subjects also. The reader is referred to the records of subjects 2, 3, 7, 9, 10, 11, 12, 13 and 15.

Of the same nature as muscular movements, are the associations of various objects. Most subjects visualized the pendulum and clocks, large and small. Several referred to the conical pendulum, striking three or four times in a swing, and others to revolving wheels. Subject 14 visualized a series of dots, and subject 11 at one time an undulating line, and at another an ellipse with four dots placed upon either side. Subject 15 made a color association.

The question we have to decide upon is, are these muscular movements and associations the result or the conditions of the rhythmical grouping? With Ribot we accept without hesitation the latter.

Ribot states this principle, "Every intellectual state is accompanied by physical manifestations.[1] Thought is not—as many, from tradition, still admit—an event taking place in a purely supersensual, ethereal, inaccessible world. We shall repeat with Setchenoff, 'No thought without expression,' that is, thought is a word or an act in a nascent state, that is to say, a commencement of muscular activity." Each impression as it enters into consciousness tends to find expression in a muscular movement, but the intensive changes in the series of impressions produce corresponding changes in the intensity of the sensations, which must find expression in different degrees of muscular activity. In order to express these different degrees of sensation, the muscular movements must rise above the merely nascent state in which they ordinarily occur, and manifest themselves in visible muscular

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[1]The Psychology of Attention.

movements. The tendency for sensation to find expression in visible muscular movements is stronger with children and primitive peoples than it is with highly civilized and especially well-trained persons. With the latter class, muscular movements accompanying attention do not so easily rise above the nascent state.

Exact coördinations of sounds with respect to intensity are difficult, for the reason that great degrees of difference must be allowed, that two sounds may be discriminated. This is proved by the fact that higher groupings of 4-groups are difficult, for the reason that the differences in the accents cannot be kept clear. Groups of six and eight are difficult because the different degrees of intensity required cannot be discriminated. Pitch changes are much more easily discriminated, and more exact coördinations are possible. They find their expression in different degrees of tension in the muscles of the larynx. With fast rates the intensive changes recur more rapidly, and hence call for more rapid muscular movements. On this account the faster rates were found exhilarating and animating, and the slower rates drowsy and soporific.

For the same reason, subject 12 found that a change from a 3-group to a 4-group gave rise to a feeling of a slower pace. Within certain limits the mind can easily accommodate itself to changes of rate. A rate which seemed unpleasantly slow or fast at first, became in time pleasant. If the rate is slow, the grouping which is first suggested is accompanied by a feeling of suspense—subject 11 said the group broke off with a "dead end"—but if it is fast there is a straining after a longer group, or perhaps a hurried, animating feeling which becomes monotonous. If a subject maintained a 2-group, for instance, with a rate which was naturally too fast for grouping by two, it became exceedingly monotonous in a short time.

If the length of the group corresponds to the normal wave of attention, the grouping gives rise to a feeling of satisfaction and repose. There is probably not an absolute psychic constant in attention which admits of no variations, without feelings of dissatisfaction, but within limits a constant is easily established, which, if changed gradually, accommodates itself to a longer or a shorter interval. A sudden change, however, cannot take place without difficulty. For this reason, if the grouping enforced by an irregular recurrence of an accented sound change rapidly from one form of grouping to another, it gives rise to an alternation of feelings of suspense and straining which no one fails to perceive. The same phenomenon would arise if the temporal sequence of the impressions were irregular. Either it would be necessary to group now by three and now by four, or by two, that the interval between

the successive accents should be the same, or there would be an alternation of feelings of suspense and of straining to maintain a grouping by three or any other number. When the rate was changing rapidly, as it did just after the chronoscope was started (it required ordinarily about two minutes for the chronoscope to attain its full speed), subject 4, especially, and others remarked upon the diagreeable effect. The accommodation to any form of grouping within certain limits is easy, providing there is a perfect regularity in the sequence. The accents must recur at regular intervals, and the number of intermediate impressions remain the same, or there is no feeling of rhythm. When a slow rate was succeeded by a faster one, it gave rise generally to a disagreeable effect; but in time the subject could accommodate himself to it. Subjects 4, 9 and 15 make observations upon this point. Subjects 2 and 5 were greatly puzzled over a 5-group which was accented on the first and third sounds. They attempted to group by two and by three alternately, which gave rise to a very disagreeable feeling. When, however, they grasped the regular sequence of five, the disagreeable feeling passed away.

When a longer interval was introduced into the series, the impressions coming between the long intervals fell together into a group, but they did not form an organic unity. There was no pleasure in such a rhythm. Something seemed to be looked for in this longer interval which was wanting. When the rate was made very fast, the impressions between the long interval seemed to fuse together into a single impression and then to group by two or four.

This general principle may be stated: *The conception of a rhythm demands a perfectly regular sequence of impressions within the limits of about 1.0 sec. and 0.1 sec. A member of the sequence may contain one or more simple impressions. If there are a number of impressions, they may stand in any order of arrangement, or even in a state of confusion, but each member of the sequence must be exactly the same in the arrangement of its elements.*

The application of this principle to poetry demands that the accents in a line shall recur at regular intervals; it requires also that the successive feet in a line shall be of precisely the same character. The introduction of a 3-syllable foot into an iambic verse is allowable on this condition only, that the 3-syllable foot can be read in the same time of the two, so that there shall be no disturbance in the temporal sequence of the accents. This foot affects the rhythm in so far only as it changes the character of one member of the sequence. This is an actual disturbance to the rhythm, but it is allowable for the purpose of emphasis. The frequent

use of such a foot would be fatal. Poe's principle that the regular foot must continue long enough in the line, and be sufficiently prominent in the verse to thoroughly establish itself, is perfectly valid. In a musical rhythm, however, the measures may vary with certain restrictions in the arrangements of their elements. But it is just this variation which constitutes the melody to a certain extent. The rhythm is varied for purposes of melody, but it is, nevertheless, a disturbance to the rhythmical flow in so far that it changes the measure. The melody is a new and higher unifying agency, which corresponds in a way to the use of rhymes in poetry. The temporal sequence of the accents is always preserved.

It remains now to make my acknowledgment to those who have assisted in the work.

To President G. Stanley Hall I am indebted not only for the subject itself, but for a large amount of material which he had already collected upon it; also for suggestions as regards the direction of the experiment and references to literature.

To Dr. E. C. Sanford, the director of the laboratory, is due much of the credit for the success of the work. But for his skill in devising and constructing apparatus, the work could not have been carried on. His suggestions as regards methods for making the experiment were no less valuable than his assistance in devising apparatus. To all others who so generously gave up their time to sit through long and tedious experiments, I acknowledge my indebtedness. Space forbids me making special reference to each one.

Clark University,
Worcester, Mass.
August, 1893.

MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY.

Communicated by E. B. TITCHENER.

I.

"MEDIATE" ASSOCIATION.

By H. C. HOWE, A. B.

Our object was the investigation of the "mediate" association, in Scripture's sense *(Ueber den associativen Verlauf der Vorstellungen: Phil. Studien*, VII. pp. 60 ff. Espec. pp. 81 ff.). The literature of the problem answers the question as to the occurrence of this form of association both negatively and affirmatively, in terms of experiment and criticism (Wundt: *Bemerkungen zur Associationslehre: Phil. Studien*, VII. pp. 329 ff. Espec. pp. 360, 361. Münsterberg: *Beiträge zur experimentellen Psychologie*, Heft IV. pp. 1 ff. Espec. p. 9. Titchener: *Mind*, N. S., I. pp. 226, 227; II. p. 235). Our experiments were carried out with six subjects: Messrs. Hinman *(H.)*, Irons *(I.)*, Knox *(K.)*, Leighton *(L.)*, Smyser *(S.)*, and Watanabe *(W.)*; in the months January to mid-March, and April to June, 1893. Two days' experimentation was devoted to practice in each case. The experiments were of two kinds.

(1) Auditory experiments.

The subject was seated in a dark room. To him were read regularly and distinctly *(a)* a series of six words, each word having a nonsense-syllable attached to it; *(b)* a second series, with the same nonsense-syllables; *(c)* the first series again, the reader waiting after each word for the subject to state his first association. All pauses were controlled and kept as constant as possible. The lists at first contained monosyllabic English words. For these were substituted, later, pairs, of which the one term consisted of English, the other of Latin, French or German words. In the course of 557 experiments there occurred eight apparent cases of "mediate" association, distributed as follows:

Observer.	Expts.	Cases.
H.	123	3
I.	36	0
K.	160	2
L.	26	0
S.	154	2
W.	58	1

These were, however, variously explicable. *(a)* In four cases the observer was able to state that he had directly associated, mentally, before association was called for by the experimenter. *(b)* Twice the word recalled was the first word in a series. *(c)* Once the word recalled was the most "striking" or unfamiliar word in a series. [It was also a first word; so that this case has been already counted, under *(b)*.] *(d)* Once the observer remembered the whole second series of words, in their order. The first series was not called over in order as first given, but the place of the recalled word had by chance escaped change. *(e)* One case remains unexplained.

Remarks.—This was the first part of our work. The subjects, at the outset of their practice, were unduly impressed with the importance of the nonsense-syllable. They associated with the word called either the syllable, an extraneous idea, or nothing. The extraneous association was ruled out for experimentation, the subject being required to make his association within the series. He then did give words of the corresponding series: but, if the correct word, always by simple memory. Throughout, too large a share of the attention appeared to be directed upon the nonsense-syllable. Error thus arising is very difficult to eliminate. We guarded against it so far as possible, but put no great faith in this whole method. Again, in the case of all of our subjects, the visual memory was stronger than the auditory. If word and link were visually presented, a second view of the word recalled a visual image of the link in its former position; but during the presentation of an auditory series, each word seemed to blur the memory-image of preceding words.

(2) Visual experiments.

Scripture's apparatus was reproduced (*Phil. Studien*, VII. p. 36), and his procedure exactly followed, except that for the 4″ limit a 2″ limit was substituted (p. 54). Our practice-experiments suggested this as an improvement. We found a source of error in the shortness of Scripture's series: the subject is able to memorize. Moreover, if two word-series were employed, we discovered that the subject was apt to associate together words of the same series. These difficulties were overcome by the employment of a series of six pictures and a word-series of equal length. That the observer should have no trouble in naming his associations, we arranged the experiment in such a way that a picture series was always shown in the third place. As links we used variously colored rings of various sizes, and small variously colored figures (diamond, triangle, fleur-de-lis). The aim was, of course, to present an object which should be perceived, but not apperceived; which should neither be conspicuous nor very readily named. Finally, since the subjects tended still to associate links rather than words, they were urged to concentrate their attention more strongly upon the pictures and upon the words. More could not be said by way of direction, without their being informed of the precise nature of the problem. Of these experiments we performed 961. There occurred 72 apparent cases of "mediate" association, distributed as follows: (See table on opposite page.)

These were, again, variously explicable. *(a)* In 21 cases the observer was able to state that he had directly associated, mentally, before association was called for by the experimenter. *(b)* In nine cases, both word and link were given as association; but the word was given first. [Six of these come also under *(h)*, one under *(f)*, and one under *(g)*.] *(c)* In twenty cases a picture called up the picture following it, independently of the word. [Seven, also, under *(h)*, seven under *(i)*, four under *(i)* and *(g)*, one under *(g)* and *(h)*.] *(d)* In five cases association took

place through an extraneous connecting idea. [One, also, under *(f)*.] *(e)* Once the word recalled was the most "striking" word in a series. [Also under *(f)*.] *(f)* Seven times it was the first word in a series. [Four cases also under *(i)*, one under *(b)*, one under *(d)*, one under *(e)*.] *(g)* Eight times it was the last word in a series. [Once also under *(b)*, once under *(i)*, four times under *(i)* and *(c)*, once under *(c)* and *(h)*.]

Observer.	Expts.	Cases.
H.	224	15
I.	71	1
K.	238	14
L.	33	3
S.	196	9
W.	199	30

(h) Sometimes the whole list was memorized, links and words; but, in naming the association, a link or a word would slip the observer's memory. Seventeen cases. [Seven also under *(c)*, six under *(b)*, one under *(c)* and *(g)*.] *(i)* Or, in naming the association, both word and link were given, but the word first. Seventeen cases. [Eight also under *(c)*, four under *(f)*, one under *(g)*, one under *(b)* and *(f)*, three under *(c)* and *(g)*.] *(k)* The word was mentally imaged before the picture was shown. [Seemed to cross other rules in two cases. These could not be arranged under *(e)*.] *(l)* The word was remembered as being at a particular point of the series, though the remaining words were forgotten. One case. *(m)* Three cases remain unexplained. One of them occurred in a series, one word of which had been inadvertently omitted, so that only five were given.

Remarks.—The observer *W.* is possessed of an exceedingly accurate pictorial memory. His thirty apparent cases were those which threw most light on the various origins of the whole number.

Results.—We have, in 557 auditory experiments, found one unexplained case of apparent "mediate" association; in 961 visual experiments, two or three such cases. These instances may be referred either to chance, to deficient memory on the part of the observer, or to deficient analysis on the part of the experimenter. So far as our experiments take us, we may conclude, against Scripture, that "mediate" association does not occur. On the whole, the appearance of the phenomenon is a function of attention. We do not consider that the method employed is wholly satisfactory. Even in the visual experiments there are operative many conditions which lead to error in result and which are hardly eliminable. "Free" associations alone can, we think, form the basis of a certain experimental conclusion in any similar department of associative investigation.

[*Note to the foregoing.*—Mr. Howe's experiments have suggested to me a source of error in the determination of the time-value of the verbal associative reaction. This source of error consists in the fact that the "associated" word may be, and will often tend to be, a word which is not associated to, but already apperceptively combined with the stimulus. When Wundt "associated" *Wind* to *Sturm*, in 341σ (*Phys. Psychol.*, II. 3d Ed. p. 315), he was obviously completing the apperceptive combination *Sturmwind* (cf. the *Kirchthurm* of p. 385). This error, it would seem, can only be circumstantially eliminated.—E. B. TITCHENER.]

II.

"Sensorial" and "Muscular" Reactions.

By A. R. Hill, A. B., and R. Watanabe, Ph. M.

In the course of his investigation *Ueber den Hautsinn* (Archiv für [Anatomie und] Physiologie, 1892, p. 311), Dr. M. Dessoir writes: "Ich müsste nun eigentlich mittheilen, ob von mir und meinen Versuchspersonen sensoriell oder musculär reagirt worden ist. Ich kann das leider nicht, weil keiner der Herren [8] bei Benutzung des Fingercontactes [p. 309] den Unterschied zu stande brachte." With the ordinary key ("an dem gewöhnlichen Tastapparat"), on the other hand, the two reaction-values were obtained.

It is a well-known fact that not every person examined in a psychological laboratory proves to be a capable reaction-subject. Some cannot react with any constancy; some never reach the quickness of the muscular form; some, while reacting constantly, do not conform to the Lange type. (See, *e. g.*, *Phil. Studien*, VIII. 138, 403 ff.) Into the reasons for these individual differences we do not wish here to enter. We have rather proposed to ourselves for answer the special question: Is the sensorial-muscular difference entirely conditioned by the technique of the ordinary reaction-experiment? Or can that difference be obtained from practised experimentees under other conditions: with, *e. g.*, the Dessoir finger- or the Cattell lip-key?

Our experiments were carried out in the months January to mid-March and April to June, 1893. We used the Hipp chronoscope (new pattern) in Dessoir's way (lower magnet only; pp. 306, 307); and tested the instrument by Wundt's new fall-hammer (*Phil. Studien*, VIII. 145 ff.). The apparatus was arranged on the Leipzig plan, in two rooms. Dr. Scripture, of Yale University, kindly allowed his mechanician to construct for us a Dessoir key. The stimulus was, throughout, the sound caused by the dropping of an electric hammer upon its ambos. Unfortunately, our fall-hammer was injured at the end of March, and from that time on we were compelled to rely exclusively upon the chronoscope. The previous test experiments had shown that, while the latter instrument was generally reliable, the mean variation of its control-times was apt to be somewhat greater than that of the times of the old pattern clock. This result, which is confirmed by that of some preliminary tests carried out in the Leipzig laboratory, points to the need of a thorough chronographic examination of the new chronoscope, in its four possible modes of functioning. This examination we hope to be able shortly to set on foot. Our present figures, therefore, possess: (1) no *absolute* (chronographic) value, except in so far as they are borne out by the results of other published investigations; and (2) even a *relative* value only in the rough. They are, however, sufficiently accurate for the answering of the question under investigation.

Nine persons took part in the experimentation: Miss Fanning *(F.)*, Miss Hannum *(Ha.)*, Messrs. Hill *(Hi.)*, Irons *(I.)*, Knox *(K.)*, Major *(M.)*, Schlapp *(S.)*, Titchener *(T.)* and Watanabe *(W.)*. Practice consisted in the taking, on four different days, of four series of twenty experiments of either type; the experimentee being required to direct the attention upon movement or stimulus, as the case might be.[1] The reaction-movement with the ordinary key consisted in the snapping-off of the index or second finger

(according to the constant preference of the reagent) of the right hand from the button to the table; not in the raising of the whole hand, or of hand and arm, from the key.[2] With the Dessoir key, it was the opening of the closed thumb and index finger of the same hand; with the Cattell lip-key (*Phil. Studien*, III. 312), the opening of the closed lips.

Our control-experiments, January-March, gave the following result: determinations recorded, each of ten experiments, twenty-two; average chronoscope reading, 186.1σ; average mean variation, 1.9σ; mean variation of average reading, 6.06σ; mean variation of average mean variation, 0.8σ. All numbers in the following tables have been reduced to this average reading, except those whose authority is the chronoscope alone; these are distinguished by a prefixed *. The first column gives the name of the observer; the second the reaction-time; the third, the mean variation of the separate times; the fourth, the number of experiments; the fifth, the number of experimental series; the sixth, the mean variation of the average times obtained from the separate series:

TABLE I.

Muscular Reaction to Sound.

1	2	3	4	5	6
S.	123.4	12.5	29	3	3.4
F.	126.2	7.6	37	3	2.8
Ha.	111.7	8.2	66	5	6.3
I.	125.0	13.0	15	1	——
W.	123.7	16.6	27	2	3.3
Hi.	120.2	15.4	20	2	3.1

The seventh column in Table II. gives the time-difference between the sensorial and muscular forms.

[1] We do not understand Dessoir's remarks in this connection, p. 312.

[2] This form of movement, proposed by Professor Wundt, was also employed in the reaction-investigation of *Phil. Studien*, VIII. 138 ff.

TABLE II.

Sensorial Reaction to Sound.

1	2	3	4	5	6	7
S.	206.5	18.7	28	2	30.0	83.1
F.	217.0	28.0	36	3	12.6	80.8
Ha.	206.1	25.1	32	4	10.9	94.4
I.	227.3	38.7	15	1	—	102.3

No experiments were recorded for *W.* and *Hi.*

The two following tables show the results obtained with the Cattell lip-key:

TABLE III.

Muscular Reaction to Sound. Cattell Key.

1	2	3	4	5	6
S.	128.0	10.0	1	15	—
F.	129.9	15.4	3	33	1.5
Ha.	118.7	18.0	2	30	11.2
I.	123.9	15.2	4	48	8.4
W.	158.0	17.0	2	21	2.0
Hi.	122.5	11.4	2	23	13.5
T.	137.3	12.1	2	20	16.5
(*K.*	122.8	20.6	4	40	19.6)

TABLE IV.

Sensorial Reaction to Sound. Cattell Key.

1	2	3	4	5	6	7
F.	218.3	20.6	6	70	8.8	88.4
Ha.	243.3	34.7	3	30	2.9	124.6
(*I.*	202.3	37.1	3	34	16.2	78.4)
W.	250.0	13.8	3	21	14.9	92.0
T.	254.4	22.5	2	20	2.6	117.1
(*K.*	131.0	25.2	4	35	11.5)	

Remarks.—III. *F.* gave many premature reactions. The "sensorial" time of *S.* tended to be central (Martius), but both the extreme forms occurred, and the mean variation of the result was very large, IV. *I.* gave typical central times. The reagent himself stated that he was unable to fulfil the conditions of the sensorial reaction. The reagent *K.* made no distinction between the forms from the outset, and was not educable. His type is the muscular, but his large mean variations prove his unsuitability to function as reaction-subject. III. *W.* seems to show a slight leaning towards centrality. It is curious to compare I. *I.* with III. *I.*, but the difference is so slight that the apparatus may be to blame for it. *Hi.* gave a central (204σ) for a sensorial time, admitting, like *I.*, his inability to concentrate his attention on the sense-impression.—It is obvious that our experiments are not directly comparable with those of Cattell (*Phil. Studien*, II. 305 ff.).

The two final tables show the results obtained with a Dessoir finger-key.

TABLE V.

Muscular Reaction to Sound. Dessoir Key.

1	2	3	4	5	6
F.	* 157.2	15.8	8	86	11.0
I.	* 152.8	14.8	3	24	5.6
W.	* 161.0	16.2	3	28	6.6
Hi.	* 155.0	13.0	1	9	——
(*K.*	* 136.1	21.6	9	91	24.4)
(*M.*	* 117.6	12.2	5	50	13.4)

TABLE VI.

Sensorial Reaction to Sound. Dessoir Key.

1	2	3	4	5	6	7
F.	* 313.0	23.2	8	80	28.1	155.8
I.	* 306.0	28.3	3	28	16.7	153.2
W.	* 300.0	23.6	3	27	30.6	139.0
(*K.*	* 123.3	14.7	9	106	9.6)	
(*M.*	* 113.7	13.7	4	44	1.5)	

Remarks.—Three sensorial series taken from *I.* gave valueless results, the subject finding a difficulty in handling the key. One series showed a central form of reaction, 182.7σ; mean variation, 7.5σ. This has not been employed in the construction of Table VI. *Hi.* again gave a central (*203σ; mean variation, 21.8σ) for a sensorial time, and again declared his consciousness of the nature of the result. He had, throughout, but little practice. The results obtained from *K.* are similar to those of Tables III., IV. Practice brought about no alteration in them. Those of *M.* are parallel with these. *K.* had not had practice with the ordinary reaction-key. M. had used neither this nor the lip-key.

We would conclude from our experimentation:

(1) That the new pattern chronoscope requires a thorough testing before its times can be accepted as of absolute value.

(2) That the sensorial-muscular difference is not, as Dessoir thinks, a matter of the form of the reaction instrument. We have obtained the difference with three reaction-keys, involving diversity of muscular action. It averages, in these cases, 90σ, 105.5σ, and *149.3σ.

(3) That we may confirm the view that not every person is able to function as reaction-subject. Rather is there required for the work a special kind of mental disposition or *Anlage*. If the volitional temperament is unfavorable, practice will have no effect in determining the two types of reaction time; if favorable, Lange's distinction holds even of the first practice-experiments.

AN EXPERIMENTAL STUDY OF SOME OF THE CONDITIONS OF MENTAL ACTIVITY.

By John A. Bergström.

Introduction.—The experimental work described in this paper was done at Clark University, at intervals during the two academic years of 1891-'92 and 1892-'93. The first part gives an account of some experiments upon the daily variations in the rate of certain mental processes, with a view to determining whether there is a natural rhythm of mental activity or not. Under the head of constant daily variations, the results have been grouped to exhibit certain types of mental periodicity. Accidental causes of variation have as far as possible been avoided, though such as barometric changes, which the experiments of Dr. W. P. Lombard and pathological observation have shown to be important, have necessarily occurred. The relative variation of a number of different processes has also been studied. The great instability of the nervous system and the numerous causes of variation prevent the results from being as definite as could be desired, but some general facts may be determined with a fair degree of probability.

The second part, in which more satisfactory experimental conditions were possible, consists of experiments upon physiological memory and is thus a distinct topic; but it has certain bearings upon fatigue and nervous activity which will here be especially considered.

The work has been done chiefly under the direction of Dr. E. C. Sanford, but I wish also to acknowledge my great indebtedness to President Hall and Dr. W. P. Lombard and those who have given their time to the experiments.

Methods.—Two classes of experiments have been selected as tests—one being the repetition of old, the other the formation of new associations. To the first belong reading, adding and multiplying of numbers, and the classification of words; to the second, the learning of nonsense syllable and number series and the sorting of cards. For the number experiments use was made of the columns of Bremiker's logarithmic tables. The vertical columns containing the fifth and sixth places of the logarithms are sufficiently irregular in order in the first fifty pages of the book, if four or five pages be discarded, to serve as material for the experiments. The tables have a further advantage in that the horizontal lines dividing the columns into groups of ten make counting of the amount done easy. The two end figures of each logarithm were multiplied or added, and as many of these operations as possible made in a minute. The figures were read either by ones or by threes with the abbreviated form of expression—thus, "seven-fifty-three," instead of seven hundred and fifty-three. Reading by threes was substituted for

reading by ones, because a certain order would often recur, while in reading by threes, the figures were perceived as a combination and no repetition noticed. In the few experiments with the classification of words, uniformly printed newspaper articles were used. The classification was based upon use. A test of the rate of voluntary movement was also employed in a few experiments. The plan was to simplify the ordinary writing movement, as far as possible, so that there should be no considerable qualitative change, and at the same time to make the amount of work done easy to count. Ten parallel lines were drawn across ordinary ruled paper, thus making ten squares on any horizontal line. These squares were filled with five crosses or ten strokes. The number made in a minute was taken as a test. This number could be seen at a glance. A convenient test of the precision of movement may also be found by using this ruled paper. With a fountain pen or a needle point make a dot or a needle prick, and then attempt to put the pen or needle point in the same place. The number of errors will be inversely proportional to the precision. Of course a given movement and rhythm must be chosen. If five dots are made in each square, counting of the errors will be easy.

An inexpensive but accurate timing apparatus was made for use in these experiments. A pointer on the second's axis of a clock dipped into a drop of mercury and thus made the circuit of an electric bell. This gave minute signals. For fractions of a minute, stars with the required number of points could be put upon the second's axis. By putting stars with the required number of points upon the minute axis, signals can be had for any number of minutes. Here large errors would probably come in if the closing of the current was made to depend upon the slow moving minute star. The circuit is, therefore, so arranged that both the minutes and the seconds points must be in their respective drops of mercury simultaneously before the circuit is closed. This makes the signal depend upon the movement of the second hand; and since there is only one point to consider, and not the distance between two successive points, the errors are very small.

The nonsense syllables were learned by the method used by Ebbinghaus. A series usually contained ten syllables. The number-series consisted of thirty digits, learned by threes. The series were read over in a given rhythm and the attempt made to repeat them. As soon as there was hesitation over a syllable, the reading was begun with it and continued to the end, and then an attempt was again made to repeat the series. The series was considered learned at the first perfect repetition. The card-sorting memory experiment consists of sorting a pack of eighty cards into ten different piles. Each pile is to contain eight cards bearing the same word or picture. In subsequent experiments different arrangements of the piles were used, so that as a memory experiment it consists essentially, like the nonsense syllable series or the memory span test, of learning different permutations of the same symbols. Care was taken that there should be no possibility of association or grouping of the words or pictures. As a memory experiment, it is especially valuable for the study of the interference of associations. The time of all the memory experiments was taken by a stop watch.

Only such material was used in the experiments as was of uniform quality and of practically unlimited amount. The comparative uses and value of the different tests is to be judged by the results. As regards errors, the effort was made to correct

them and thus include their value in the total time of the operation. In the experiments upon the daily variations in rate, the general plan was to make experiments every two hours throughout the day. The effect of practice and fatigue for the tests themselves was reduced by preliminary practice to a comparatively small quantity. The influence of the interference of associations in the memory experiments is more troublesome; but at the end of two hours its effect is small, so that great changes must be due to other causes. The results of a number of days were then averaged, giving the constant daily variations. The subject of the experiments was asked to be as regular as possible in his habits, and to follow an average routine of work and rest. This is, of course, an essential requirement. In the majority of cases it was quite carefully complied with. Since large changes in the tests themselves have been eliminated, any such that occur will be due to general changes in the nervous system and the circulation.

Constant Daily Variations.—Table I. aims to give a general view of the changes in rate throughout the day. The figures under morning, afternoon, and evening represent seconds; and for E. C. S. give the average time required for learning three series of nonsense syllables of ten each at those times of day. The rest give the average time required for sorting two packs of cards in the way described. Two similar packs were used by W. O. K., and by A. F. for the first average. In all the other experiments, two different

TABLE I.

	Morning.	Afternoon.	Evening.	No. of Days.
E. C. S.	478.3	544.	573.3	10
M. N.	188.7	197.	214.	11
J. A. B.	211.94	225.66	249.7	7
P. E., Av.	±1.99	±2.07	±2.32	
L. N. B.	225.4	224.3	269.6	11
A. F.	{ 269.4	264.4	288.8	8
	{ 223.49	216.85	244.3	8
W. O. K.	288.4	300.	282.2	6
P. E., Av.	±2.09	±2.48	±3.19	
E. T.	200.34	196.45	193.4	5

packs were used. Differences in manipulation will make it impossible to compare the rates of all the different subjects, but this was constant for any given one. The right hand column gives the number of days from which the average was made. Usually there were four experiments in the morning and three in the afternoon and evening each. The morning average of E. C. S., for example, is made up from forty experiments—or one hundred and twenty series. A low record indicates rapid rate, and a high record the contrary.

The records of three other subjects averaging ten days each, but covering only the morning and afternoon, show no decided difference between these two periods.

The averages show that the rate of the first three subjects diminishes throughout the day, while that of the next two is as good or better in the afternoon, though poorer in the evening. The rate of E. T. increases steadily. W. O. K. makes the best records in the evening, but is poorer in the afternoon than in the morning.

Only the probable errors of the records which do not receive special study in Table II. are given. The daily variations in rate are not of a single type such as would be required if a natural, inherited rhythm of activity existed. The daily rhythm is the resultant of a number of nervous and circulatory influences, which will be discussed after a statement of the results has been made.

Table II. gives a more detailed statement of the records which are adequate as regards number, and regularity of experimental conditions for such treatment. The probable errors—as a measure of the closeness with which each subject adheres to his type and of the reliability of the experiment—are greater than they should be since the effect of practice is added to that of accidental variation. Only a rough correction can be made, however, and the general results can be established without such correction. The effect of practice can be seen in the averages of the successive days. For L. N. B. there is an average decrease of about three seconds per day at first, the last four days being nearly the same. A. F., whose preliminary practice was considerable, shows no decrease of time. The records of M. N. diminish about four seconds the first four or five days, after which the averages are about the same. Those of T. L. B. decrease about one second per day. The effect of practice in these cases has evidently little influence upon the daily curve. The experiments of E. T. extend over only five days, but they were made very carefully and are of special interest, since they represent a distinct type. The effect of practice during the experiment can be seen from the averages of the five days, which are 203.67, 202.28, 202, 195.54 and 184 respectively. The great increase of rate on the fifth day is probably not to be attributed so much to practice as to change in health. With the exception of an experiment in which a subject sorted cards for an hour or more continuously, no signs of fatigue for this experiment itself have been observed. A few trials were made to see if a second experiment would give different results from the first, especially when an unusual record was made. The two records usually differed but slightly, if the effect of the interference of association is taken into account. In another experiment with four other subjects, about as many experiments were made in an hour as were here made in a day, but no evidence of fatigue is to be seen, though the average endurance is probably no greater. The general effect of the interference of associations is to make the first of a series of records shorter than the second, while the rest will not differ much from the second. It would not influence the general curve of the day except with respect to the first record in the morning, which would be shorter than it should

be. The fact that with more intense work the interference is slightly greater is a disturbing element, however, which needs to be taken account of. The amount of the changes and the individual peculiarities of the curves show at a glance that they are not due to small and comparatively constant changes in the experiment itself. The experiment of E. C. S. was performed at three different periods, three days being used the first and second time and four the third. The averages of the records for the three periods stand

TABLE II.

	A. M.				P. M.						
Hours.	7.30	8.30	10.00	12.00	2.00	4.00	6.00	7.00	8.30	10.00	Number of days.
L. N. B.	234.2	218.1	225.8	223.6	215.8	231.2	226.	253.	280.8	275.	11
P. E.	±2.2	±1.8	±2.89	±1.79	±1.76	±3.3	±2.79	±2.	±4.	±4.16	
A. F.	233.4	229.4	216.8	214.3	213.3	211.9	225.3	244.6	236.3	250.4	8
P. E.	±4.32	±4.21	±2.8	±3.8	±2.29	±1.33	±4.3	±3.8	±3.68	±5.8	
Hours.	7.30	8.30	10.00	12.00	1.30	3.00	6.00	7.30	9.30		
M. N.	192.8	185.	183.6	193.4	186.3	197.1	207.6	207.2	222.6		11
P. E.	±4.4	±3.24	±2.7	±2.55	±3.5	±3.5	±3.	±5.	±3.7		
E. T.	198.	205.3	204.5	193.54	197.6	199.3	192.45	201.6	185.2		5
P. E.	±4.8	±4.6	±4.7	±4.48	±2.4	±1.5	±3.48	±3.3	±1.8		
Hours.	7.45	9.00	11.00	12.45	2.00	4.00	5.45	7.00	9.00	10.30	
E. C. S.	452.7	484.7	467.9	508.	531.4	507.7	593.	536.3	578.	605.6	10
P. E.	±12.48	±19.4	±13.44	±16.53	±25.49	±14.24	±20.98	±14.76	±20.47	±15.01	
Hours.		8.00	10.00	12.00	2.00	4.00	6.00				
T. L. B.		179.7	189.4	187.8	190.7	189.3	192.7				17
P. E.		±3.6	±2.1	±2.56	±1.84	±1.33	±2.63				

as one hundred to eighty-six and seventy-nine respectively, but in each of the sets of days there was an increase rather than a decrease of time, showing fatigue rather than practice. The effect of interference was so slight that it can't be demonstrated between successive series. It is believed that changes in the experiment itself are inadequate to account for the great daily variations. A three days' experiment with card-sorting gives variations corresponding with those for the nonsense syllables. The general daily routine differed a little with the different subjects, but in general the hours of sleep were from 10 to 7; breakfast was eaten immediately after the first, dinner after the 12 o'clock, and supper after the 6 o'clock experiments. With the exception of E. C. S. the subjects were between twenty and thirty years of age; E. C S. is a little over thirty. All were members of the psychological department except M. N. and E. T., two ladies, one of whom is a student of medicine, the second a teacher. All were in good health during the experiments except E. T., who had not yet recovered from a severe attack of nervous prostration. The constant daily variations of E. T. will be seen to show the typical symptoms of morning tire and depression after meals, though the rapid rate at all times shows that there is no lack of power to concentrate.

The accompanying chart will give the general picture of the daily variations at a glance. The first curve shows that breakfast and dinner are stimulating. The middle of the morning and afternoon shows lower rates than the beginning and end of those periods. The high records and consequently low rate after supper is probably due to a habit of relaxation at that time. The subject complained of sleepiness. The better record at 10 P. M. than at 8.30 P. M. may be accidental, but is probably due to the fact that 10 to 12 P. M. were found to be good hours for study in college and had been so used. The subject took tea or coffee morning and night, but evidently not in sufficient quantities to give the characteristic effect of meals, since the records after breakfast are low, while those after supper are high. The curve of A. F. does not show any decided effect of meals. The records after meals seem rather to take their proper place in the general tendency of mental activity to increase or diminish. Coffee or tea was taken at each meal. The first two records show a morning depression. L. N. B. was up, on the average, thirty minutes earlier than A. F. and felt wide awake, while A. F. complained of sleepiness in the morning. From 10 A. M. to 4 P. M. there was a steady increase of mental activity. At 6 and 7 P. M. the records are higher, in spite of recreation and supper. The time from 8 to 10 P. M. was usually devoted to study, and the better record at 8.30 P. M. is probably due to the increase of mental tension. Early morning and evening depression, with an intermediate period of constant activity, is the characteristic of this curve. The curve of M. N. is marked by a decrease in rate during the day, interrupted by the stimulating influence of meals. Tea or coffee was usually taken at meals. The curve of E. C. S. shows a decrease of rate from morning till night. The low rate before dinner and supper is a noticeable feature. After supper there is a marked increase of rate. The effect of breakfast and dinner is not certain, on account of the large probable errors, though the average is higher in both cases. The curve of E. T. differs wholly from the rest. It shows an increase in rate throughout the day interrupted by depression after meals. Tea or coffee was usually taken at meals.

Accidental Variations.—At the suggestion of Dr. W. P. Lombard a comparison of all the records with the barometric readings was

FIG. I.

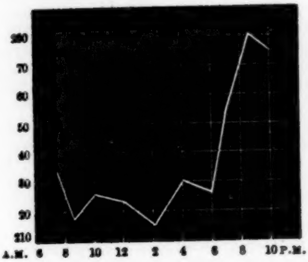


FIG. II.

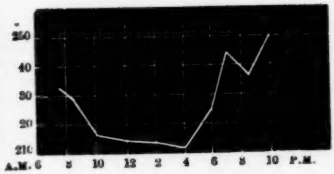


FIG. III.

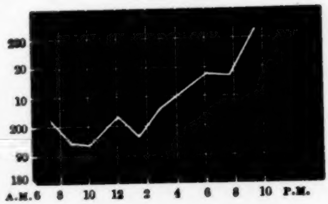


FIG. IV.

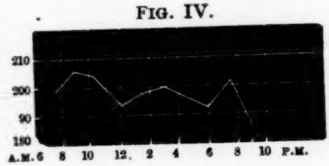


FIG. V.

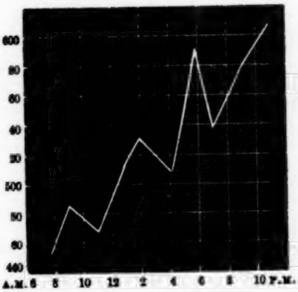
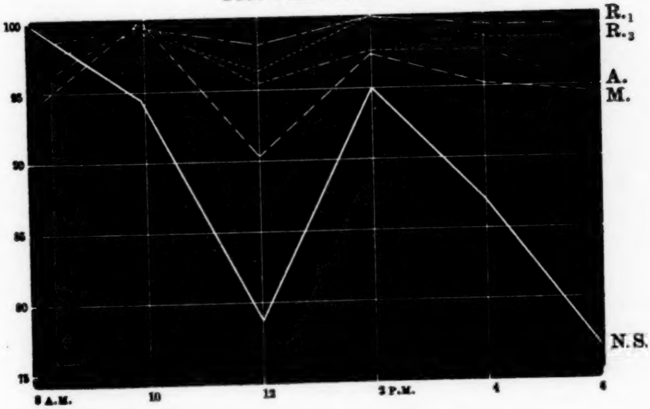


FIG. FOR TABLE IV.



made. The method adopted was the following: The curve of the average representing the constant daily variations was plotted over the curve of variations for each day. The state of the barometer, whether rising, falling or stationary, was then marked upon the curve for the day. The constant barometric variations, with maxima at 10 A. M. and 10 P. M., and minima at 4 A. M. and 4 P. M., are very slight in this latitude and can only be demonstrated by the average of a large number of days. The great fluctuations are irregular. The direction of change of the daily curve from the average is of course either the "same" or "above" or "below." The classification of these changes of direction under rising, falling and stationary barometer gives the results in Table III. The first two subjects evidently show no dependence upon barometric

TABLE III.

		Rising.	Falling.	Stationary.
	Above.	14	19	12
	Below.	15	19	11
L. N. B.	Same.	13	9	3
	Above.	13	13	3
	Below.	14	11	4
A. F.	Same.	6	4	4
	Above.	7	21	17
	Below.	17	13	13
T. L. B.	Same.	3	1	9
	Above.	9	22	8
	Below.	13	12	8
M. N.	Same.	1	4	6

changes, since there are about as many records above as below the average for the various states of the barometer. T. L. B., whose records are very variable, though showing no constant daily changes from 8 A. M. to 6 P. M., gives a preponderance of low records for rising and high records for falling barometer. The same is true of M. N. in a less degree. There would seem to be a correspondence between rapid rate and rising barometer and poor rate and falling barometer in the last two cases. Observations sufficient to establish a safe independent proof of the influences of barometric changes should be more numerous than those we have, on account of the improbability that such slight changes of quality and distribution of the blood as ordinary barometric fluctuations probably produce, will have any effect on the mental processes. The results may be taken to support the view that some people are largely influenced by barometric variations, while others are not. Most of the experiments were taken in March, April and May, so there were in general no extreme temperature changes.

The charts of a Draper self-registering barometer were kindly supplied for the work by Mr. Martin Green, of Worcester.

Other causes of variation occur only a few times. They are mainly external and such as tend to concentrate or distract the attention—though some are of a purely physiological nature.

The Relative Variation of Different Processes.—Table IV. gives the result of an eleven days' experiment by the writer. Six experiments were made a day, beginning with 8 A. M. At each experiment the pulse rate was noted; and then the rate of reading, adding and multiplying numbers, and of learning nonsense syllable series, was obtained in the way described above. Four ten-syllable series were learned each time. A uniform daily routine was maintained—8 to 10, reading of psychological literature; 10 to 12, reading and listening to a lecture; 12 to 2, dinner and recreation; 2 to 4, laboratory work; 4 to 6, walk and recreation. The experiment required from fifteen to twenty minutes each time. For the sake of ready comparison the results have been reduced to percentages, the quickest record being counted 100. The numbers for the nonsense syllables are the inverse of the times required, so as to correspond with the other records. Since the question is here how much can be done in a given time, and not, as in the former case, how long will it take to do a fixed amount, the meaning of high and low records is the reverse of that in the previous tables—a high record meaning rapid rate and a low record poor rate. At the best time it required, respectively, 0.325, 0.346, 0.857, 0.907 seconds for reading a number in a set of three, by ones, and adding and multiplying two together, inclusive of pronunciation; 110 seconds were required for a ten-syllable series at this stage of practice.

The right hand column M. V., which gives the mean variations of the six averages of each test, shows the relative amount each changes under the same physiological influences. With respect to the amount of variation, the tests may be arranged in a series, beginning with the reading of numbers by ones and ending with the nonsense syllables. The same series will be formed if they are arranged in the order of complexity or difficulty, the time required being taken as a measure of the difficulty. An exception must be made of reading by threes, though this is probably a more complex process than reading by ones, in spite of the fact that less time is required per figure.

Some facts may be found here for deciding what test would be most serviceable in similar experiments, and how far variations in the rate of certain processes may be taken as an index of changed

TABLE IV.

	A. M.			P. M.			
Hours.	8	10	12	2	4	6	M. V.
$R._1$	98.27	99.71	97.92	100	99.13	99.2	.765
P. E.	±1.10	±.59	±.97	±.80	±.61	±.85	
$R._3$	97.23	99.29	96.04	100	98.59	98.37	1.02
P. E.	±1.21	±.82	±1.10	±1.52	±.92	±.76	
A.	95.29	100	95.7	97.57	97.57	94.86	1.55
P. E.	±1.53	±1.43	±1.67	±1.68	±.90	±2.	
M.	93.8	100	90.32	97.43	95.01	94.4	2.37
P. E.	±1.01	±1.04	±1.84	±1.22	±1.43	±.87	
N. S.	100	94.24	78.5	94.9	86.88	76.06	7.95
P. E.	±3.16	±3.98	±3.54	±3.72	±3.36	±5.10	
Pulse.	66.9	62.2	62.6	66.8	65.4	65.2	

$R._1$ and $R._3$ refer to reading numbers by ones and by threes respectively; A. and M. to multiplication, and N. S. to the nonsense syllable series.

physiological conditions. If only very slight, or even no change could be observed in the simpler processes, very striking variations might, nevertheless, be found in the more complex ones. These facts are in harmony with the common experience that easy work can be done almost any time, while the most difficult work can only be done well at rare intervals. The easier tests might be difficult for persons weakened by sickness and so give considerable variations. Reading of numbers would perhaps be sufficiently difficult in many cases to indicate the more considerable fluctuations. With opportunity for plenty of experiments, the most difficult test will give the most striking and satisfactory results; but with only a few experiments no conclusions could be drawn on account of its great irregularity. The greater regularity of the simpler tests makes fewer experiments necessary, but the variations will be very small if demonstrable at all.

A glance at the cut will show that with one exception the variations of the different processes are the same throughout the day. The exception is the nonsense syllable record at 10 A. M. This does not, like the rest, show an increase of rate at 10, though it is not

certain that it shows a diminution. The time between 8 and 10 was occupied with reading, and the result is probably due to a differential effect of this kind of mental work upon the two kinds of processes. The interference of associations is quite marked in the case of the subject. This would account for a small part of the difference, but it should theoretically only affect the first series at 10 A. M., making that a little longer than it would be without the record at 8 A. M., so that the influence would be much too small by itself to account for the result. The variations of the processes under the influences of rest and dinner, fatigue and exercise, it will be seen, are the same. A test of the matter, by exclusion, between 8 and 10 A. M., was not made on account of lack of time. The increased mental excitement at 10, shows itself in greater rapidity of well learned processes, but also by the presence of unconscious tendencies to distraction, which make themselves known by increasing the time of learning the nonsense syllables. At 12 M. there is a decrease of all the processes, but at 2 P. M. a considerable increase, after dinner and rest. Four and 6 P. M. again show poor records.

The fact that easy operations hardly change at all, while the more complex show considerable variation, was the first result noticed in the preliminary experiments, and formed the basis for further work. In a five days' experiment by two subjects, the following times were required for sorting an ordinary pack of playing cards into four piles at the times of day designated. Three records were made at each experiment. Though the process is far more complex than simple reaction, the changes in it are very small:

TABLE V.

	A. M.		P. M.			A. M.		P. M.	
	9	11	4	10		9	11	4	10
	53.33	50.66	51.2	53.93		53.1	51.4	51.7	57.1
E. C. S.	19.95	19.81	19.3	19.1	J. A. B.	22.9	21.7	21.6	24.9

The first row gives the hour of the experiment; the second, the average time required for the sorting; the third, the time for distribution into four piles *without sorting*. The records of E. C. S., with the nonsense syllables, were taken at a different time, but otherwise under the same conditions, so that a rough comparison may be made. It is evident the ability to learn nonsense syllables changes much more during the day than the ability to sort cards into so few positions. A similar rough comparison of the variation of card memory test for the writer, gives 2.6% as the mean variation of the six records of the morning and afternoon. This makes it stand between multiplication and nonsense syllables in its sensitiveness to variations, though much nearer multiplication than the other. Another series of experiments of four days, besides preliminary practice, with the classification of words and the test for the rate of movement, gave the following results, which, though taken at another time, correspond quite well with those of Table IV.:

TABLE VI.

J. A. B.

A. M.				P. M.					M. V.
7.15	8	10	12	2	4	6	8	10	
262.5	272.5	278.5	267.75	277.25	270.75	269.75	260.25	260.75	1.97%
120.75	132.	135.	124.	135.5	135.5	140.25	131.5	120.	4.52%

The first line gives the hours, the second the number of strokes per minute, the third the number of classifications made in two minutes. Only a rough comparison with Table IV. is intended. The mean variations in the right hand column show that the classification of words undergoes the greater changes.

The experiment, the first eleven days of which gave Table IV., was continued thirty-two days longer, with various changes in the memory test. On ten of these days the regular occupation from 4 to 6 was changed to exciting physical exercise—ball playing or tennis. The results are shown in Table VII. The memory test was not the same on the different days, since they were made for a different purpose. It consisted, usually, of two number series alternating with two nonsense syllable series, but other combinations occurred. The probable errors cannot therefore very well be calculated, but the extraordinary change in rate does not leave any doubt of its existence. It will be remembered that with ordinary quiet recreation there was, on the whole, rather a decrease than an increase of rate at 6. The intermediate days, on which no exciting exercise was taken, show this also. If the 6 o'clock records are put at 100 and the 4 o'clock records expressed as percentages of them, another proof is obtained that the variation of the more difficult processes is relatively greater under the same physiological changes, which may be either *depressing* or *stimulating*.

Some of the 6 o'clock records were made immediately after the exercise, others after about a half hour, but the effect was nearly the same. In the third series of experiments upon the parallel law for lifted weights, Fechner brought on intense muscular fatigue by lifting nine and one-half pound weights in a rapid rhythm. The exercise aroused his whole system, as a very rapid pulse rate indicated. The number of right cases increased instead of diminished after the operation. In a fourth series of experiments, in which the weights were lifted slowly, though the fatigue operation was performed five times in succession, so as to get a cumulative effect, only a comparatively small increase of the pulse rate was noticed, and the number of right cases after the operation is about the same as that before. It seems not unfair to say that these experiments show that with a general physiological change—in this case of a stimulating nature—there is a corresponding change of the power of discrimination, even if this does not change with local fatigue of the sense organ, which latter fact Fechner had especially in view. The analogy with the experiments reported in the last table is, of course, evident, though in the one case rate, in the other

TABLE VII.

	4 P. M.				6 P. M.			
Date.	$R._3$	A.	M.	N. S.	$R._3$	A.	M.	N. S.
April 4.	210.	73.	70.	322.7	221.	77.	78.	352.3
" 5.	205.	77.	59.	362.7	219.	76.	74.	243.3
" 10.	216.	79.	73.	172.25	228.	88.	67.	150.75
" 11.	207.	80.	56.	217.8	232.	83.	74.	112.8
" 19.	222.	83.	72.	252.8	232.	96.	89.	148.
" 26.	198.	86.	88.	153.5	219.	91.	97.	89.8
May 5.	217.	89.	89.	241.	240.	94.	98.	158.3
" 6.	216.	89.	87.	297.	243.	105.	103.	198.5
" 10.	217.	92.	88.	196.	237.	100.	101.	168.8
" 11.	214.	85.	85.	301.5	235.	101.	103.	220.5
Average.	212.2	83.4	76.7	251.72	230.6	91.1	88.4	184.31
	92.02	91.5	86.7	73.2	100.	100.	100.	100.
Pulse.	67.3				85.4			

$R._3$, A. and M. refer to reading by threes adding and multiplying respectively; N. S., to the nonsense syllable series.

discriminative sensibility, is measured. The stimulating effect of exciting physical exercise is a matter of common experience. A mathematician, who kindly replied to a circular of questions regarding habits of mental work, finds the first hour and a half after a game of tennis especially valuable for original work. Fechner attributes the increase of the power of discrimination to the acceleration of the circulation. As will be seen later, certain changes in the nervous system probably coöperate with this to produce the result.

Tables IV. and VII. give some data for a study of the relation of the rate of mental work to the circulation. In experiments with the plethysmograph and balance, Mosso and others have shown that any mental activity from a simple sensation to the solution of a problem is accompanied by an almost instantaneous alteration of the circulation. The theory of Mosso that, in this case, the cerebral

circulation increases while the peripheral diminishes, seems to be based upon too few observations. According to Féré, moderate and pleasant mental activity may be accompanied by an increase of the peripheral circulation, while intense or disagreeable mental effort is marked by a depression. The same author says the tipping of the balance toward the head does not necessarily show an increase of the cerebral circulation, since the majority of organs which express the emotions are on the head side of the centre of gravity. Direct tests of the intracranial blood pressure make it probable, however, that mental activity is accompanied by an increase of cerebral circulation, though the actual amount of blood in the brain does not change very much, since the skull is a closed cavity. M. Gley found a dilation of the carotid, a contraction of the radial artery, and an increase of one to three pulse beats per minute during hard mental work. Leumann, in some experiments upon boys in a gymnasium, found that the normal scansion of poetry was in direct ratio to the pulse frequency. He also explains the so-called apperception rhythm of minimal differences of sensation and the periodic umbrations of mental images as due to the influence of respiration upon the circulation. This subject will be referred to again in the discussion of the results.

A comparison of the rapidity of the pulse with the rate of the mental processes, in Table IV., will show that there is no necessary correspondence between the two. The pulse rate falls from 8 to 10, while the rate of all the processes but the nonsense syllables increases. The pulse rate is about the same at 12 as 10, but the rate of all the processes has diminished. For the afternoon there is a fairly close correspondence. The lack of correspondence between the pulse rate and mental activity is much more striking in the following experiment, which, though it failed in its direct aim, has several points of interest. The object was to study the effect of one kind of work carried on till considerable fatigue appeared, upon another kind of work entirely different. In experiments with the ergograph, Mosso found that Dr. Adduco made a better record in the middle of a four or five hour period of exciting mental work than at either the beginning or end. No measure of the mental work is made, so it is impossible to say whether the increase and decrease of the test work coincided with similar changes in the main work. The object here was to measure both kinds of work, substituting tests of the rate of mental processes for the ergograph record. The translation of German was the main work. Adding, multiplying and reading of numbers and the experiment upon the rate of movement were the test work. A record with the tests was made at 8, 10 and 12 in the morning. The rest of the time from 8 to 12 was divided into eight equal parts by the stroke of a bell. The subject (C. H. J.) translated with the greatest possible rapidity, marking off at the strokes of the bell the amount done. The experiment was made on twelve days, but only the last seven were under proper conditions. Scientific German had been taken up as a study only a few weeks before. Wundt's "Physiological Psychology" was the book read. The number of words for which the dictionary had to be used was also noted. It was supposed that with advancing fatigue they would become more numerous. The experiments were made the first part of August.

TABLE VIII.

No. of lines.	23.8	25.1	29.9	25.9	27.9	24.2	28.1	29.4
P. E.	±2.98	±2.46	±1.61	±3.39	±4.78	±.95	±1.54	±3.03
Unknown words.	7.	7.1	6.7	7.6	7.6	7.4	6.9	6.9
P. E.	±.39	±.35	±.44	±.52	±.46	±.42	±.53	±.44

The first horizontal row gives successively the number of lines translated in each of the eight equal divisions.

The table below gives the rate of the test processes at the times mentioned. The probable errors of the tests are given in the right hand column at the given hours.

TABLE IX.

8 A. M.		10 A. M.		12 M.		
71.3	±2.3	60.7	±1.82	53.	±.39	Pulse.
97.4	±1.46	101.2	±1.26	102.6	±.86	Addition.
64.4	±.74	63.3	±.69	61.7	±1.51	Reading.
81.	±.79	81.	±1.08	81.6	±.62	Multiplication.
260.6	±1.27	268.4	±1.68	268.7	±1.86	Movement.

A possible source of error is that there may have been an unconscious allowance for the amount which had to be done. Toward the end of the four hours' work there was a severe feeling of fatigue, but there is no corresponding diminution of rate either in the main work or test work. After dinner there was a disinclination to effort of any sort. A glance at the records will show that the rate of the main work and the other processes is nearly the same throughout. During the first five days, a recess of fifteen to twenty minutes was taken between 9 and 10. With that routine there was an increase of all the processes at 10, and a diminution at 12, as in Table IV., and there was no feeling of fatigue after dinner, but work was usually taken up at once. The noticeable thing is the great change in the pulse rate, namely, from 71.3 to 53, while there was no change in the rate of the mental processes. The high pulse rate at 8 A. M. is due to the breakfast which has just been eaten, and there is a similar increase after dinner. While an increase of mental activity probably causes an increase of blood flow to the brain, mental activity can evidently not be said to vary with the pulse rate.

Discussion of Results.—The experiments, so far reported, show that the subjects, whose records cover the entire waking period,

have a well marked periodicity of mental activity. There is, however, no *general* type of daily rhythm, and individual differences of the most striking sort occur. The same influences have different effects upon different individuals. The more complex mental processes have relatively greater variations than the simpler. Under the influence of fatigue, rest and physical exercise, the processes studied vary in the same direction. Statistical investigations show that those who are engaged in mental work have generally observed a daily rhythm of power. In connection with other questions, Heerwagen sent out the following: What part of the day do you find mental work easiest? To which, 182 said the morning, 133 the evening, six the afternoon, forty-three noticed no difference, while twenty-eight found it easy at all times. Professor Earl Barnes, in a study of the intellectual habits of Cornell students, received in reply to the same question, sixty-six votes for the morning, six for the afternoon and thirty-nine for the evening. The average student, he says, sleeps eight and one-fourth hours, begins work at 8, but is in doubtful condition, is best at 9, at 10 still in good condition, at 11 he is tired and at 12 is at his worst. He works from 3 to 5 in the afternoon, but in inferior form. After supper he goes to work at 7, and reaches his best at 8. From 9 P. M. he is not at his best, and at half past ten goes to bed. The smallness of the number who chose the afternoon is probably due to the hard work of the morning which all had. Forty-five said their power was uniform from day to day, 109 that it was variable. Three-fourths accounted for the variations by the weather, dry, clear days being approved, dull, damp days denounced. The state of feeling, regular sleep and meals were the causes next in order of importance. Many said they were less able to work after a rest than when they had gotten at it. Thirty-eight said they could get the most rest in an hour's time from exercise, thirty-one from sleep, twenty-three from a walk, six from light reading, four from a bath and three from music. The location of the best hours depends largely upon the hours of retiring and rising. It will be seen that actual measurement and statistics of opinions both show that in a certain number of cases there will be persons whose maximum activity comes at almost any given hour of the waking period. The rhythm of activity may or may not correspond with the actual energy at the person's disposal. Other things being equal, the total amount which can be accomplished decreases as the interval since sleep increases, but the rate of work may be most rapid a little before retiring, as in the case of E. T. and W. O. K. While most persons thus recognize the existence of a daily periodicity of activity, which is of great importance for the quality and quantity of work they can do, this does not conform to any general type, and is, therefore, not an inherited modification of the nervous system. The daily rhythm is the result of a number of stimulating and depressing causes, whose influence habit tends to fix upon the system. Changes of hours of work are often made, though with more or less difficulty.

Some of the answers to the circular sent out by the writer state that a change from evening to morning work had been made. The evening hours were still preferred, but had to be abandoned, because they were "expensive" and sleep was interfered with.

The preceding results do not furnish the material for their own explanation, except in a few points. A brief review of some of the literature bearing upon the subject may therefore be permitted. The hope of finding a thoroughly satisfactory explanation is of course not entertained; but the following facts are suggestive :

Dr. Hodge has demonstrated that nerve cells under electrical stimulation and ordinary fatigue show, for the nucleus, a marked decrease in size, a change from a smooth to a jagged appearance and a darker staining; for the cell protoplasm, shrinkage and vacuolation. The materials of the cells are highly complex and unstable, while the waste products of their activity are more simple and stable. Change from unstable to stable compounds, in this case chiefly by oxidation, is accompanied by the setting free of energy, part of which is used to build up its own substance and part as free nervous energy for the stimulation of muscles and other cells, while another part, as Schiff has shown, appears as heat. Of special interest here is the experimental study by Wundt of the relation of the anabolic and katabolic processes, and the changes of these in sthenic and asthenic conditions of the nervous system. If a strong electrical stimulus is used to test the condition of a nerve during the progress of stimulation from another current of moderate strength, its effects upon the muscle contraction will be reënforced. If a weak test stimulus is used, it is usually suppressed. This is interpreted to mean that during the excitation of a nerve there is an increase both of positive or katabolic and negative or anabolic work. The positive work predominates, especially if the nerve is in the asthenic condition from poor nutrition or cold. The fact that stimuli are retarded and weak ones, entirely suppressed on passing through the spinal cord is evidence that the stimulation of normal central cells causes an increase, especially of the anabolic process. Poor nutrition, exhaustion, cold, and various drugs, especially strychnine, produce the asthenic condition, in which the anabolic process is relatively weakened and the katabolic increased. The fact that nerve conduction is only in one direction through the central cells and that interferences of stimulation take place, gives the foundation for the assumption of regions in the central cells, in one of which the positive work predominates, in the other, the negative. The stimulation of one region causes its characteristic work to spread over the entire nerve cell, so that inhibition or excitation takes place according to the region stimulated. Here as well as in the other cases the asthenic condition diminishes relatively the inhibitory or negative work. Stimulations which would inhibit in the normal condition, in this, produce reënforcement. The fact that reënforcements of sensations and muscular movements are more prominent in neurasthenic and hysterical persons seems to be paralleled here. The greater excitability and sleeplessness in excessive fatigue are another illustration.

The activity of a nerve is a function of both the inhibiting and exciting influences, that is, of the anabolic and katabolic processes. The greater the energy of a nerve, the greater both the negative and the positive work; both of which diminish with exhaustion, especially the negative.

The results of the activity of the nervous system upon its own condition have been grouped under the summation, facilitation and diffusion of stimuli, practice, fatigue and habit. The object here is to refer to these facts simply as a means of explaining some of the daily variations observed. A series of induction shocks applied to the posterior roots of the spinal cord or to the cortical centres may produce a contraction by the summation of effects in the nerve centers when a single shock of the same strength is too weak to have any result. A reflex produced by the stimulation of a given sensory nerve will be facilitated or strengthened if, shortly before, a contraction of the muscle has been produced by the

stimulation of this or any other sensory nerve. The familiar "warming up" to work is probably to be explained in large part by these facts of nervous activity.

In the reflex animal a weak stimulation of a sensory nerve causes a contraction of the muscles of the same side; a stronger one, of those of the opposite side at the same altitude; a still stronger one, a contraction of the muscles lying higher and lower, but predominantly on the side stimulated. A nervous process set up anywhere in the spinal cord tends to diffuse itself in all directions. Similar facts are brought out by experiments upon men, though for this purpose hysterical patients give the most striking results. Féré has shown that the muscular power measured by the dynamometer is greatly increased by previous movements on the same side, and slightly increased by movement upon the opposite side. Any mental activity augments the muscular power on both sides. Musical sensations have a dynamogenic power in proportion to their intensity and height. A similar dynamogenic scale may be made of colors, beginning with red and ending with violet. Sensations of taste and smell have a similar power. An increase of the discriminative sensibility for colors was also noticed as the effect of mental effort or sensory stimulation. Not only were the energy and speed of the movement increased, but also its endurance. Fatigue brought on by too long exposure to a color produced contrary results. Féré notes that reaction time does not reach its greatest rapidity till the stimulating influence of light and heat has operated for some time. Nocturnal paralysis and morning tire are explained as exaggerated phenomena of this sort. The blood distribution is in rapport with these increments of power. These facts, the reënforcement of minimal sensations by other sensations, the influence of central nervous processes upon the knee jerk and the sweat glands, the slight unconscious movements which accompany attention, and many familiar facts of the influence of mental states upon respiration, circulation and secretions, show that central nervous processes diffuse over other centres. If fatigue sets in, there seems to be a corresponding depressing influence diffused over the nervous system. The diffusion of the effects of nervous activity and their retention and summation by physiological memory are the chief facts on the nervous side, which seem to account for the increase of the rate of certain processes with hard or exciting mental or physical work. The increase of power by practice is probably also connected with these facts.

The tendency of work is thus to increase in amount till exhaustion takes place. It is a common experience that the more mental work is done, the more can be done up to a certain limit, beyond which come collapse and despondency and other symptoms of over-training.

While the nerve fibre is comparatively independent of oxygen and food supply, as is shown by the fact that it will function either in air or in indifferent gases for a considerable time after excision, the metabolism of the nerve cells is very rapid. In the experiment with Bretino, Mosso found that unconsciousness and convulsions were produced by only a few seconds' compression of the carotids. The hole in Bretino's skull made the reduction of the blood supply easy, since this was not opposed by the atmospheric pressure. The muscles of the arm still respond to the will after the blood supply has been shut off for half an hour. This shows that nerve cell metabolism is much the more rapid. Dr. Corning has also experimented with compression of the carotids to reduce hyperæmia,

and study the effect of diminution of the blood flow upon mental processes. Compression of both carotids was followed by facial pallor, drooping of the eyelid, dilation of the pupil, soporific tendency, dizziness, heaviness and confusion of ideas, and finally by syncope. He notes that dizziness and confusion of ideas come more quickly if the compression was made toward evening than if made in the morning, which points to fatigue of the brain cells at evening. The latter result would probably not be generally true. Account should be taken of the different rhythms of mental activity, which, as has been shown, is not a problem capable of a general solution.

The great influence of qualitative changes of the blood stream upon nervous activity is well known. Asphyxia can be produced by suspension of breathing for a few minutes. The poisonous atmosphere of crowded rooms produces headache and various other nervous troubles. Especial interest attaches to the qualitative changes of the blood in connection with the theory of fatigue. The poisons of various contagious fevers are probably the waste products of various bacteria. The activities of the cells of the body similarly produce waste products which are more or less poisonous. Washing a fatigued muscle will restore it. Mosso found that the injection of the blood of a tired dog into the circulation of a fresh dog produced in the latter all the signs of fatigue, while a similar injection of blood from a fresh animal had no such effect. Mosso attributes the decrease of muscular power after the four or five hours' intense mental work in the experiment referred to above, as due to the poisonous effect of brain work. Choline and neurine, decomposition products of lecithin, one of the chief constituents of nervous tissue, which may be formed in cell metabolism, have a poisonous effect like curare. Xanthocreatin, which appears in physiologically active muscles, produces depression and excessive fatigue. The presence of uric acid in the blood produces marked symptoms of mental depression and irritability. According to Haig, the neurasthenic symptoms of morning tire and depression after meals are to be attributed to its influence. Its presence depends upon the alkalinity or acidity of the blood. If the blood is alkaline, it removes uric acid from the tissues; but if acid, it causes its storage. By making the blood artificially acid or alkaline, symptoms of depression or exaltation can be produced at will. He assumes that there is an alkaline tide in the morning, after meals and in the spring, to account for depression at those times. In this connection, it is of interest to compare the psychometric investigations of Kraeplin, Münsterberg and others on the effect of drugs upon the mental processes. Experiments with the ergograph upon muscular power have usually shown that the effect of meals was stimulating. In the experiments reported in this paper, three subjects showed a decided stimulating influence of meals, but one showed as marked a depression from them. The effect is probably not a constant one for the same person, but varies with his power of digestion. In the experiments by the writer in Table IV., the stimulating effect of dinner is well marked. In another series of experiments, extending over fifteen days, but not reported here, a depression after meals was equally well marked, while the general daily curve was otherwise the same.

The term fatigue includes a number of facts, not all of the same kind. Its fundamental idea seems to be diminution of power from excessive work. It refers also to the painful feeling accompanying such work. Sometimes it is applied to the decrease of rate of work. If the energy, rate of work, and feeling of fatigue varied concomi-

tantly, so that one could be taken as the symbol of the other, this use of the word would be convenient. In the experiment of C. H. J. there was a severe feeling of fatigue at 12 M., but no corresponding decrease of rate of work. If energy is measured by the endurance still possible, this evidently diminished from the start. In the so-called second stage of fatigue, there is fatigue anæsthesia, a high rate of activity, but an actual store of energy less than in the preceding state of normal fatigue, as is shown by the after effects of the experience. The true physiological condition is not, however, open to direct inspection, but must be inferred from the blunting of the sensibility, the failure of mental processes, and the accompanying feeling of pain, together with various physical signs, such as loss or gain in weight. The rate may not run parallel with the store of energy, but may be ahead or behind, according to various stimulating and depressing causes. According to Cowles, mental symptoms are the most sensitive accessible indices of exhaustion. The order in which they appear is depression of spirits, decrease of voluntary control, morbid introspection, and finally, diminished sensitiveness.

The curve of fatigue calculated by Dr. Hodge from the shrinkage of nerve cells shows that fatigue is first rapid, then slow, and again rapid under continuous stimulation. The curve of recovery is symmetrical with it. He compares this with the somewhat similar curve of muscle fatigue obtained in experiments with the ergograph, where central rather than peripheral fatigue is really involved in many cases.

Bowditch and others have shown that nerve fibres are not easily exhausted. The sense organs differ greatly with respect to fatigue. The sensibility of taste, smell and sight falls off rapidly under stimulation. The retina seems also to undergo daily changes. To two observers, objects seemed twice as bright in the morning as in the evening. Fatigue of the ear comes on more slowly, but has been demonstrated for high tones and loud momentary sounds. Local fatigue for certain tones has also been shown to occur. Stumpf thinks his discriminative sensibility for tones is greater in the evening than in the morning; but as this depends upon the mental processes rather than upon the condition of the ear, this may be due to the fact that his mental activity increases towards night. A continuous series of discriminations of pitch from morning till night, with an intermission for dinner, was made by H. K. Wolfe to study the effect of fatigue upon the number of right cases. In spite of painful fatigue, no diminution in the number was observed. It is to be noticed that he was in good training for this kind of work. Within certain limits, fatigue for a sense organ does not involve a diminution of the power to discriminate. Fechner calls this the parallel law, because it is to be looked upon as the application of Weber's law to inner physiological changes. His experiments have already been referred to. v. Kries found that two lights appeared the same relatively, whatever the fatigue.

That the daily rhythm of mental activity is much influenced by habit is a familiar fact. A brief habituation to certain hours of sleep is sufficient to leave a tendency to sleep at that time. The subject of Experiment VIII. had been accustomed to a short rest in the middle of the forenoon, the month before the experiment. The effects of this seem to show in the records, the average of which for the first three days are 18.3, 20, 26.3, 15.3, 12.7, 21.3, 22.7, 22.3. There is no evidence of its lasting longer. This influence is in part analogous to that of certain eccentricities of eminent men.

Many writers feel the need of being in particular spots, of using peculiarly colored paper or ink before they can do well. Rousseau found composition difficult unless he was walking. Neander composed best lying on his stomach. Coleridge liked to compose when walking over uneven ground. Sheridan composed at night with a profusion of lights around him. Lamertine had a studio of tropical plants. Dr. George Ebers imagines himself more at liberty to write with a board on his lap than at the desk. Vacano composed at all times, but the place he was in was important, and he could write best in the hubbub of peasant life near an old mill. Maurice Jokai must have fine pens and violet ink. These habits, however acquired, evidently have great power of distracting the attention if they are not satisfied, and so retard work. As a positive influence, they may serve as a sort of hypnotic signal for the state of composition. Similarly certain times, certain occupations may serve as a signal for rest or activity during the day. The increase or decrease of mental excitement may thus be due to no special physiological change, but to the influence of suggestion and habit, and they are factors which should be taken into account in mental or physical training as well as the more prominent physiological facts.

Other Experimental Work upon the Subject.—In his experiments upon memory, Ebbinghaus found it required twelve per cent. more time to learn a sixteen syllable series from 5 to 7 P. M., than from 10 to 12 A. M. Oehrn notes incidentally a single trial of one hour in the morning and one hour in the evening by two subjects, one of whom added faster in the morning than in the evening, while the other did the contrary. Dr. W. P. Lombard, in experiments with the ergograph, found a remarkable twenty-four-hour periodicity of the power of making voluntary muscular contractions. Both in the experiments upon the causes of variation in the knee-jerk, and in these just referred to, a marked influence of barometric changes was noticed. Rising barometer was followed by an increase, falling barometer by a decrease of muscular power. The actual barometric height was unimportant. The constant daily variations had their maxima at 10 A. M. and 10 P. M., and minima at 4 P. M. and 4 A. M., thus corresponding with the constant barometric changes. Daily variations from the constant curve followed the accidental fluctuations of the barometer. While there is a little evidence that two subjects were influenced by barometric changes in the present investigation, there is none for such a daily periodicity. In his case, the effect of the slight regular changes of pressure is supposed to have become organized into the habit of daily variations referred to. Dresslar found a daily rhythm in the rate of tapping which seemed to correspond with his habits of work as teacher for the two previous years. The rate was increased by exciting mental work, but diminished by long walks.

PART II.

Some experiments upon memory by means of the interference of associations were reported in the AMERICAN JOURNAL OF PSYCHOLOGY, Vol. V. No. 3. The object here is to give an account of a few additional experiments and especially to show the influence of interference upon mental activity. Table X. gives a summary of the results of the article referred to. The memory experiment consists of sorting two packs with the same words or symbols successively into different positions. On the average sixty-five seconds were required for the first pack, but eighty-five for the second, if

this was sorted immediately afterwards. The difference is called the interference time, since it is due to conflict of associations and not to fatigue. The time for sorting the cards decreased considerably with practice, but the amount of interference did not. The average of the interference time for the first four subjects, the first seven or eight days, is 17.10 seconds, for the next seven or eight days, 17.53 seconds. This shows that it is not a temporary phenomenon which a little practice may obviate. The interference time is not due to fatigue, since, if two packs with different symbols are sorted in succession and the order in which they are used is changed to compensate for differences in them, the average of the first pack for four subjects is 62.89, for the second, 61.99, showing no increase. If there were general fatigue of the attention or of the nervous susceptibility, that would show itself by an increase of the time of the second pack with different words. The effect might be due to local fatigue of a striking sort; but three facts set aside this hypothesis. Less time is required for the second pack if the cards are sorted into the same places as before. In sorting pack after pack with the same symbol continuously for an hour or so, the time of the first is short, that of the second long, that of the rest is about the same as the time of the second, showing only toward the end a slight tendency to longer records, which may be due to fatigue. The chief fact which shows the nature of the process is the very

TABLE X.

	3″	15″	30″	60″	120″	240″	480″	960″	Number of Experiments.
F. D.	26.62	21.59	20.69	21.08	20.11	15.88	13.56		112
P. E.	±1.23	±1.25	±1.5	±1.45	±1.18	±.96	±.97		
O. C.	17.33	13.48	14.18	13.45	10.66	11.72	11.34		126
P. E.	±.91	±.74	±1.17	±1.26	±1.26	±1.25	±1.18		
M. E. B.	28.79	23.66	19.89	17.34	13.57	13.09	10.08	7.79	94
P. E.	±.70	±.92	±1.20	±1.01	±1.31	±1.23	±1.62	±1.11	
J. A. B.	33.09	25.18	20.42	15.76	13.75	12.	11.04		147
P. E.	±1.2	±1.07	±1.1	±.83	±.81	±.65	±1.04		
T. L. B.	21.85	21.42	17.88	12.25	10.02	11.2	10.25		66
P. E.	±2.28	±2.19	±1.87	±2.14	±2.02	±3.96	±1.44		
Average	25.54	21.07	18.61	15.98	13.62	12.78	11.25	[7.79]	

great tendency of some subjects to make false motions in the direction of the places the cards were in for the first pack. The delay can be seen to be caused by the actual making of a great number of incorrect movements. To a large extent interference is unconscious. With the longer intervals where the interference amounts to twenty or twenty-five per cent., the subject frequently feels no trouble. With the shorter intervals there is usually great confusion, but the false movements are not known to be such till they have been made. This shows the reflex nature of interference. The sorting of cards involves the learning of new associations and requires an intense effort of attention, any distraction of which causes a great lengthening of time. Interference demonstrates experimentally certain relations of mental activity and memory to the nervous system, since its persistent, involuntary, reflex nature proves it to be physiological. It shows that even such complex processes after a very few repetitions are carried on largely by reflex activity; and that reason comes in chiefly in case of error. The first horizontal row gives the intervals between the two packs. The following rows give the amounts of interference for the different subjects as the interval increased, together with the probable error.

The general feature is a rapid decrease of interference at first, with a very slow diminution afterwards. The attitude of the subject is to forget rather than to remember the previous positions.

Interference in the other memory experiments has only been studied upon the writer; 226 series of nonsense syllables, ten each, were learned from March 20th to March 31st. Four series were memorized each time, with about ten seconds' interval between to give an opportunity to mark down the result. A similar experiment was made with number series, each containing thirty digits. Three series were learned each time. There are eighty-eight in all. The average of those which were learned in the first, second, third and fourth places gives the following result:

	1	2	3	4
Syllables.	104.55	131.05	134.78	137.16
Number.	271.75	302.12	306.96	——

The time of the second series is considerably longer in both cases, but the increase in time after that is very slight. A similar result is found in Ebbinghaus' records. The average of ninety-two groups of eight twelve-syllable series gives for the successive series 105, 140, 142, 146, 146, 148, 144, 140. The great increase of the second above the first and the slight difference afterward is noticeable. The same difference between the first and second is to be found in his other experiments. The series whose averages are given was taken at the beginning of his experimental work and shows a slight increase of time up to the sixth, which may be due to fatigue. In subsequent experiments there is no such increase, but after the great lengthening of time for the second series, there is a certain oscillation above and below the average with no evidence of fatigue. Ebbinghaus notes especially the rhythmic oscillation of the averages. The odd series were learned more quickly than the even. He attributes it to a rhythm of the atten-

tion or the sensibility, but does not explain the fact further. The interference of association will explain the sudden increase of the time of the second and probably also the rhythm of the odd and even series. As has been said, nonsense syllable series are essentially different arrangements of the same symbols. The opportunity for interference thus exists. To test the matter experimentally, nonsense syllable and number series were made up from the first half and the last half of the alphabet and digits respectively. Nonsense syllable and number series could now be learned in succession without interference. If the lengthening in time took place nevertheless, fatigue might be the cause. Series of nonsense syllables and numbers were also learned alternately, thus shutting out interference. The result shows that when interference is avoided, no increase of time takes place. The fact that reading written and printed letters may be learned separately, gave rise to the theory that if the second series was written and the first was printed, or vice versa, interference might be avoided, but this was not verified. Interference will therefore explain the increase of time of the second. It is also an influence which is fitted to give rise to the rhythm noticed by Ebbinghaus. The third series is probably learned more quickly than the second, because the interference from the first has died away, and the second series was not learned so well and does not retard so much as the first did the second. Since the third is learned more quickly, the interference again becomes greater for the fourth, so that if the oscillatory variation is set up it would tend to perpetuate itself.

Two series of numbers and two series of nonsense syllables, one of each kind described, were learned at the same hours as the series last referred to. Sixty-six series of nonsense syllables and sixty-eight series of numbers give the following result:

	Syllables.		Numbers.	
	1	2	1	2
Average.	151.	138.99	228.34	193.29
P. E.	±8.21	±7.14	±10.61	±6.13

1 and 2 in the second row indicate that the series was learned in the first or second place. Fourty-four experiments, in which a syllable and a number series alternated in the first and second places, give 172.75 and 173.65 as an average. There is an actual decrease of time for the second series of numbers, while the averages of the alternating series are about the same. The experiments with the series give, of course, only an individual result, and chief reliance is placed upon the experiments of others with the cards.

The following explanation of the decrease of the time of the number series may be offered. The subject had been learning series in which all the digits appeared, for considerable time. Series containing half the usual number may be supposed to call up the absent members. There would be simply stimulation of the nervous tracts, but no formation of associations. The effects would summarize and the series containing the absent digits be more easy

to learn. The same thing is noticed in the syllable series to a less extent. If packs of cards are sorted in immediate succession the results resemble those for learning a number of series. The averages of a series of card experiments, on five different days, by F. B. D., were 113.2, 140.6, 135.4, 144.8, 148.8, 140, 139.4, 143.2, 138. The increase of the time of the second and the oscillation of the rest above and below the average are to be noticed.

That the interference is not due to any local nervous association of the centres of the eye and hand, but is the after effect of a more central or apperceptive mental process, is shown by the following experiment. Instead of actually sorting the first pack, and thus learning the associations which afterwards retard the second, the subject is asked to learn them by repetition, like nonsense syllables, till he can tell where they are. This excludes special training of the hand centres, and in case the positions are learned by ear, of the eye centres. Had the interference disappeared for sorting by hand, that would be evidence that it was due to some local association; but the fact that it appears strongly shows that the nervous process is central. Table IX. gives the results of the experiment. Under "before" and "after" is given the time for sorting a pack of cards without interference from a previously learned pack. Under "eye" and "ear" are given the time required for sorting a pack when different positions of the cards have been learned previously by seeing them on the table or by being told where they were. Under "eye" and "ear" the numbers are averages of three, so that the final average is made from twelve experiments. Different packs were used "before" and "after" on different days, to compensate. The experiment required nearly an hour each time, but it will be seen that there is no evidence of fatigue. The fact that the interference is greater when the eye is used to learn the positions on the table, is perhaps connected with the fact that the positions were learned more easily by eye than ear, the average time required being 78.9 and 126.6 seconds respectively. Some time was, of course, lost through the person who told the positions in learning by ear.

TABLE XI.

M. E. B.

	BEFORE.	EYE.	EAR.	AFTER.
	64.6	85.33	79.33	56.6
	55.5	87.53	77.73	58.4
	56.4	83.66	80.09	54.2
	51.8	88.	77.8	56.
Average.	57.05	86.13	78.76	56.3
Interference.		29.45	22.02	

After-images of all sorts are of special interest for the theory of the relation of mental states to the nervous system. The possibility of the experimental variation and measurement of interference, which may be called an after-image of central activity, makes it important in this respect. After-images and practice give, in a way, more minute and tangible, if not so full, evidence of mental and nervous concomitance as the great lines of argument from the mutual influence of bodily and psychic states, brain lesions, and comparative anatomy and psychology. The last experiment shows that similar impressions, in so far as they are identical, go to the some central tract, irrespective of what sense they were learned by. It emphasizes the importance of the central associative nervous process, and is opposed to any rigid dismemberment of the memory for facts into different sensory types, except where by this distinction is meant that the same thing can be learned more easily by one sense than by another.

With reference to the rate of mental processes, the fact brought out by these experiments is that if certain sensory data have been associated in one way, it is temporarily more difficult to make a different association of them than if the first did not exist. Table X. shows the rate at which this difficulty diminishes with time. If the interval between the two packs is twenty-four hours, the second will be sorted more quickly instead of more slowly, as is shown by the steady increase of the rate of work by practice. There are two opposing tendencies in the experiment—one, the general training of the attention and the organization of all the movements; the other, the intense associations just made by learning the positions in any given experiment. The latter is temporarily able to produce the retardation noticed, but, since it is the result of only a few repetitions, it fades away quickly, while the first is continually strengthened by practice. The resultant of the two tendencies thus makes the sorting of the second pack or the learning of the second series immediately afterwards much more difficult, but, after a considerable time, easier. The application of the fact to memory experiments and memory work generally is, of course, evident.

It has probably, however, more important applications to inventive mental work. For this view there is no direct experimental evidence, but only such general reasons as will be adduced. The influence of physiological memory in retarding the progress of thought is in some respects recognized. After reading a certain author, many persons find it hard for a time to assert their own stand-point or style. It is usually necessary to let new views sink down to the level of intensity of older views before a fair estimate of them can be made. Many have been obliged to form the habit of letting matters which arouse their interest rest over night for a fair judgment. In mathematical calculations, many persons will repeat the same error over and over again, and be temporarily unable to obtain a solution. After a few hours they return to the work and are surprised at the ease with which they arrive at the correct result. While the memory of the error was recent, it prevented the true association; but when its intensity had diminished sufficiently, the correct association again became easy and natural. Similarly, in the translation of a foreign language, the mind may have become set for a certain meaning, or some error may have crept in and the passage is for the time misunderstood. Some hours later the proper sense of the passage may appear at a glance. In investigation, there may be a clear knowledge of the end desired and the power to estimate the value of facts and theories which

bear upon the problem; but the solution is conditioned by the association of ideas. In invention of all sorts, mental processes form with difficulty, and slight hindrances are sufficient to obstruct them entirely. Many of the processes which belong to the solution of the problem do not enter distinct consciousness at all, and yet may be essential for a correct result. These are especially liable to error. Everyone has perhaps heard long debates upon such questions as: "Which should we say, that five and six *is*, or that five and six *are* twelve?" With the attention focused upon *is* and *are*, the wrong association, five and six equals twelve, is not noticed. A mathematician says that in studying geometrical figures, only a few relations can be made out at a time. Others are seen so easily some time afterwards that the wonder is they were not seen at once. In this case, one grouping of the facts produced a certain discovery which gave a given direction to interest and association. Other associations, not in the same direction, would be temporarily more difficult. With this, there may co-exist certain errors like those in computation and translation, whose intensity must die away before progress can be made. In recalling names or facts which are nearly forgotten, we sometimes succeed at once; at other times we find it impossible. A second trial a few hours after our failure may bring success at once. The resultant influence of recent experience perhaps sent the associative movement in the wrong direction. This error would still further increase the difficulty. Both influences must diminish in intensity before the correct association can take place. A persistent hunt for clues is fatiguing, but, of course, often succeeds.

As a class, these facts have usually been explained by some theory of unconscious cerebration, or they have been attributed to the summation of stimuli, or to rest.

That these phenomena are due to a summation of stimuli which gradually gathers sufficient strength to break through the nervous resistance into the correct association, seems improbable, since every nervous excitement diminishes in intensity if left to itself, and the quickest and most striking results are usually obtained by putting the problem entirely out of mind for a while.

Fatigue and rest have, as is well known, a considerable influence upon the rate of mental work, but these cases seem to occur, just as in the memory work, when there is no fatigue present. The unreliable and often fantastic character of mental processes in the indirect field of consciousness, in revery, and in dreams, the stupidity of secondary consciousnesses, together with the absence of fatigue from this imagined unconscious cerebration, makes it probable that it is of little importance, and that conscious attention is the forge in which most, if not all, valuable mental work is done.

It is not believed that the formation and fading away of certain errors and tendencies of association offer a complete explanation of these and similar facts, but simply that this influence should be given a place in any list of those which hinder mental processes, and that it is a prominent cause of the surprising retardations in the cases described.

I.

For some references and a brief discussion of the conditions of mental activity, see:

JAMES' Psychology, Vol. I. p. 80-127; and Vol. II. p. 372-382.

LADD'S Physiological Psychology, p. 102-162, and 210-236.

COWLES, EDWARD. Neurasthenia, Shattuck Lecture. 1891.

HODGE, C. F. A Microscopical Study of Changes due to Functional Activity in Nerve Cells. *Journal of Morphology*, Vol. VIII. No. 2.

Some important articles which have appeared since these books were printed, or which were not exactly in their line, are the following:

GALTON, FRANCIS. Statistics on Mental Fatigue. *Journal of Anthropological Institute.* 1888.

KRAEPLIN, DR. EMIL. Die Beeinflussung einfacher psychischer Vorgänge. 1892.

MOSSO. Die Ermüdung. 1892.

BURGERSTEIN, DR. LEO. Die Arbeitskurve einer Schul-Stunde. Zeitschr. f. Schulges, IV. 9-10.

HÖPFNER, DR. L. Uber die geistige Ermüdung von Schulkindern. Zeitsch, f. Psych. u. Physiol. der Sinnesorgane. Bd. VI. 2 and 3. 1893.

FÉRÉ, CH. La Pathologie des Emotions. 1892.

II.

References for the topic of daily variations of ability:

EBBINGHAUS. Uber das Gedächtniss. 1885. p. 95.

OEHRN, A. Experimentelle Beiträge zur Individual-Psychologie. Dissertation. 1889.

LOMBARD, W. P. (1) The Variations in the Normal Knee-jerk and their Relations to the Activity of the Central Nervous System. AMERICAN JOURNAL OF PSYCHOLOGY, Vol. I. p. 5-71.

(2) Some of the Influences which Affect the Power of Voluntary Muscular Contractions. *Journal of Physiology*, XIII. 1 and 2.

DRESSLAR, F. B. Some Influences which Affect the Rapidity of Voluntary Movement. AMERICAN JOURNAL OF PSYCHOLOGY, Vol. IV. No. 4.

BARNES, PROFESSOR EARL. Intellectual Habits of Cornell Students. *Cornell Mag.*, Nov., 1890.

HEERWAGEN, FREDRICH. Statistische Untersuchung über Schlaf und Traum. Studien, Vol. V. p. 301.

AUBERT (Sight). Grundz d. Physiol. Optik., p. 508.

STUMPF, C. (Hearing). Ton Psychologie, Vol. I. p. 358.

III.

To the references given by the writer for the memory experiments in the AMERICAN JOURNAL OF PSYCHOLOGY, Vol. V. No. 3, must be added:

EBBINGHAUS. Uber das Gedächtniss, p. 47-61.

MÜLLER AND SCHUMANN. Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Zeitschr. f. Psych. u. Physiol. der Sinnesorgane, Bd. VI. 2 and 3, p. 173. 1893.

A NEW ILLUSION FOR TOUCH AND AN EXPLANATION FOR THE ILLUSION OF DISPLACEMENT OF CERTAIN CROSS LINES IN VISION.

By F. B. Dresslar.

I recently had occasion to test the experiment described by Loeb[1] with reference to the illusion which arises in touch, when two edges are placed so as to cross each other on a level, at a moderately small angle, and the finger tip be passed along one edge and over the junction point. The illusion which he noticed is to the effect that the segments of the line along which his finger moves, appear to be raised up where they meet the diagonal line, something like the rafters to the centre pole of a roof. As he remarks, the illusion is only present when some little pressure is exerted on the edge by the finger, and not when it is run along the edge lightly.

According to the author the illusion arises from the fact that as the finger approaches the junction point, instead of all the pressure being exerted on the one edge, it is exerted on two, and in this way the finger is slightly raised, and is kept so until the junction point is passed, when it begins to sink and so gives a basis for the illusion.

There is another illusion connected with this experiment which, so far as I know, has not yet been described. Although it is quite distinct in using two edges, as Loeb did, it can be more easily shown by pricking pin holes through a card along two lines crossing in the same way as the two edges described. In Figure 1, let A D and B C represent two lines of pin holes on the roughened side, crossing at O. If the finger tip be passed along B C, toward C, when it crosses the junction of the two lines at O, A D will seem not to be a straight line, but a broken one, and the section O D will seem to be displaced and to occupy the position o′ d′. Likewise if the finger passes along A D, toward D, the line B C will appear broken, and the part O C will take a corresponding displacement. The illusion is quite striking, and the following explanation is offered:

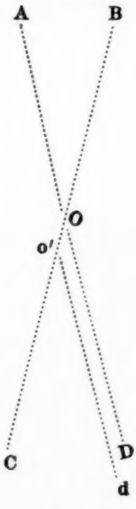


Fig. 1.

The finger, as it passes along the edge followed, touches the part of the diagonal line, making the acute angle much sooner than the other part, because the finger tip extends for some distance beyond the sides of the edge it follows, and since the ability of the finger tip to distinguish two points as separate requires a separation of these points from 2 to 4 mm., the sensation from the first one touched will have disappeared as a distinct sensation before the sensation of the other as distinct is given. And thus, from the basis of the sensation received, an apparent displacement of the line must needs follow. This view is strengthened by the fact that the illusion does not appear if the cross line is approached at a right angle. Neither does the displacement appear if a portion of the finger tip be pressed through a small hole in a

[1] Pflüger's Archiv., Vol. 46, p. 38.

card, and so fastened that only a small portion of the sensative surface of the finger be allowed to touch the edge followed.

Since a similar illusion appears for the eye, it has occurred to me that the same explanation given for the illusion of touch would answer for the illusion in vision if the fovea of the eye be considered as receiving the stimulus in the same way, or at least in a way comparable to that of the finger tip.

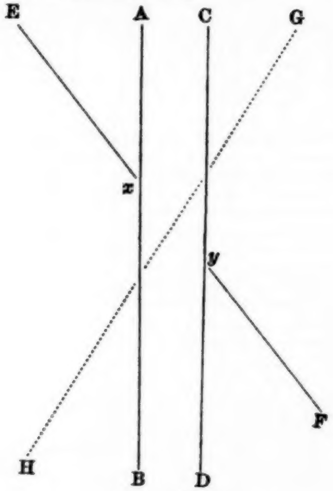


FIG. 2.

If, in Figure 2, the eyes follow the line A B, from A toward B, the point x will enter the field of clearest vision sooner than point y, and as the eye must move down some little distance before it gets the clearest view of y, the tendency is to make the displacement appear in the line, as if the point x had been met with in the same line (C D) as y, but as much higher as the difference in time of receiving the impression would indicate. The illusion still appears if the lines A B and C D be removed, but all other conditions remain unchanged.

The following observations are in harmony with this explanation:

1. The illusion is more marked when the eyes move along the line A B (Figure 2), from A toward B, than from B toward A; while in following with the eye the line C D, the illusion is greater in passing from D toward C than contrariwise.

2. The illusion disappears if the cross line be approached along the dotted line G H.

3. The illusion also disappears if the eyes be directed immediately to the point in the centre of the space between the perpendiculars which the cross line, if completed, would cut.

4. The illusion diminishes as we pass from the most sensitive part of the retina, and, when the light is sufficiently strong, in the outer part of the retina, it is wholly lost, whether the eye be in motion or at rest.

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PSYCHIC EFFECTS OF THE WEATHER.

By J. S. Lemon.

Psychology is now studied from many points of view, but the relation of psychic processes to weather has never received much attention. The subject opens a field as large as it is new, in which the writer has for some years been collecting materials. The following note may suffice to show the scope of the subject, till a fuller and more systematic presentation I hope to make ere long:

That all the world is interested in the weather is shown in the forms of salutation in every language I have been able to learn of. This interest was, of course, deeper when the race lived more out of doors; but we shall never be independent of thermometers and barometers. Things in general remain fixed, but weather is variable. What attracts attention first daily is still for most people the sky, clouds, wind, etc. What we term "weather" is a product of several variables—moisture, temperature, pressure, ozone and electricity at least. Several of these usually change together, if not all, so that to study man as a weather indicator, we need not go to the hospital or sick room, nor consider exceptional phenomena like tornadoes, cyclones and hurricanes. "Weather" is most prominent in the temperate zones, where the quantum of changes in all these variables is greatest and most frequent. Every long hot or cold term, or other exceptional state, affects the death rate. Unseasonable or anti-seasonable changes are especially fatal.

Many savage and ancient people believed deities, friendly and unfriendly to man, contended in hot and cold, moist and dry, and strove to appease storm and wind gods. From very early times, predictions have been essayed, and weather prophets have won renown. Some of the great crises of human history have been determined by weather. So that it is no wonder omens have been sought and held in high favor. That the sun plays so great a *rôle* in weather changes is one cause of the prevalence of solar myths, descriptions of storms as battles, of hostile deities, the lightning myths Kühne has collected, and from those times down to the modern sun bath, blue glass craze, hot and cold baths, ozone inhalations, electricity, weather factors have entered prominently into therapeutics. So out of the range of human control have been balmy winds and lovely skies and sunshine, that it is not strange that religious people in Christian lands and ages have been moved to seek the help of God for propitious weather. We notice in the last revision of the Episcopal Prayer Book that prayers for favorable weather, for rain, for safe voyages, for protection from lightning, etc., have been retained. So the Romans sought skyey auspices, and the Athenians prayed for rain. Atheists often become quite orthodox in storms, and the superstitions of seamen are well known. Once, when it was thought bad weather was due to Satanic

influences, Pope Innocent had a manual prepared to be used by the clergy in unfavorable weather, and for the expulsion of demons. Seneca attributed weather to certain inexorable beings and left no place for appeal to deity to change it. Very likely one difficulty monotheism has constantly had against it at every stage, is the difficulty of conceiving how one deity could produce such diverse and opposite kinds of weather.

Sidney Smith wrote: "Very high and very low temperatures establish all human sympathy and relations. It is impossible to feel affection above seventy-eight degrees, or below twenty degrees F. Human nature is too solid or too legend beyond these limits. Man lives to shiver and perspire." Seneca said: "The empire of the world has always remained in the hands of those natures who enjoy a mild climate. Those who dwell near the frozen north have uncivilized tempers." Some think clothing, which has so profoundly modified man's moral and physical constitution, was due, not to modesty chiefly at least, but to weather extremes. We seem more delicate, and less able to bear weather than our ancestors, without modern protection.

Dr. Farr, of England, and Dr. Stark, of Edinburgh, almost lead us to think morality is registered on the thermometer, so surely does it measure certain kinds of criminality. S. A. Hill, of India, believes forty-eight per cent. of crimes of violence disappear in cold weather. I shall dwell at length later upon the psychic effects of weather on the insane and idiotic, and upon certain forms of disease. Certain tendencies are repressed and counter influences set at work or made dormant. A sudden rise of temperature predisposes those liable to an attack of mania. Some patients are so sensitive to and dependent on the weather that they anticipate the thermometer and barometer. One sign of growing neurotic diathesis is inability to keep at the top of one's condition and in good tone in unusual weather. On suicides the effects of the weather are well known. The interesting little book of weather proverbs, published by the weather bureau, is a psychological treasure-house upon all this subject.

Nearly all vocations—some, of course, more than others—are affected by weather. Men of science are often as much subject to weather as seamen. Some writers must have the weather fit the mood, character or scene, and can do nothing if they are at variance. An adverse temperature brings them to a dead halt. If one will but read poetry attentively, he will be surprised to find how much of it bears weather marks, scattered all through it. A popular writer thinks weather often affects logic, and that many men's most syllogistic conclusions are varied by heat and cold. Diverse weather states may be one cause of so much diversity and even disagreement in thought processes, usually regarded as scientific. I have collected opinions of many experienced teachers, and nearly all think there should be modification of both school work and discipline to correspond with weather. Animals respond to it promptly and with no restraint, and almost constitute a sort of weather signal service if observed. Ancient prognostics were based here. Dunwoody, *e. g.*, gives lists of animals which become restless before rain.

The fact that now our property as well as our comfort depend on the weather has given weather a new power as an excitant which dwellings and clothing had lessened. Jesus, Mat. 16:23, rebukes over-sensitiveness to weather. Man should be joyful or depressed, optimistic or pessimistic over other things than this. The anxiety expressed by the directors of the world's fair about the weather of

the opening day was a strain which suggested suffering. Some have said that a certain very famous criminal was acquitted last August solely because the stifling air of the court room made it impossible to follow a severe logical argument. The weather bureau does a great work in economic psychology.

We have gathered a long list of ejaculatory expressions, and unpremeditated remarks concerning weather, which furnish data of interest. Commercial travelers often make much account of it. The head of a factory employing 3,000 workmen said: "We reckon that a disagreeable day yields about ten per cent. less work than a delightful day, and we thus have to count this as a factor in our profit and loss account." Accidents are more numerous in factories on bad days. A railroad man never proposes changes to his superior if the weather is not propitious. Fair days make men accessible and generous, and open to consider new problems favorably. Some say that opinions reached in best weather states are safest to invest on. "I never," says one, "make any important agreements or bargains when the sun shines and I am at my best." Most remarks about the weather are made in the morning, then we settle to it as an accepted fact. Women accept the weather, and, unlike men, very rarely express indignation if it is not to their mind.

Nothing is more curious than the way these ideas have been wrought into description of heaven and hell, whether in heathen, classic or Christian writings. Hell is very hot or cold, and aggravates pains of all diseases. The *Dies Iræ* was a day of wrath suggested by a day of storm and earthquake. Read the well-known hymns beginning, "Hark, hark my soul," "O mother, dear Jerusalem," "Jerusalem, the golden," and many, many others.

Laboratory investigation of the subject meets at the outset the difficulty of distinguishing results of weather changes from similar states otherwise caused. This difficulty is no greater than are many other topics of research, and we believe will not invalidate our methods and results. All our senses put us in rapport with the external world. The knee-jerk seems proven to have a weather factor. It is not strange if the eye, *e. g.*, which wants the normal stimulus, in long dark weather causes other changes. Changing moisture in the air changes odors, and many appetites are affected, as touch is still more obviously. Tea tasters work best on fair days.

Clark University, July, 1893.

PSYCHOLOGICAL LITERATURE.

I.—ANTHROPOLOGICAL PSYCHOLOGY.

A. F. CHAMBERLAIN, PH. D.

A. PAIDOLOGICAL, PEDAGOGICAL (and related subjects).

Some Comments on Babies. M. W. SHINN. *Overland Monthly* (San Francisco), XXIII. (1894), 2-19.

General discussion, supplemented by observations of the author. Illustrated by numerous drawings and photographs of infants of various races.

The Study of Children at the State Normal School at Worcester, Mass. E. HARLOW RUSSELL.

Thoughts and Reasonings of Children. H. W. BROWN. (Reprinted from the *Pedagogical Seminary*, Vol. II. No. 3), 54 pp. 8vo.

Professor Russell's paper explains and illustrates the system of child study in vogue since 1885 at the Worcester State Normal School. Mr. Brown's contribution consists of some 375 records of the thoughts and reasonings of children, classified under the following heads: Misunderstandings of words; Applications of sayings; Explanations of things; False reasoning; Thoughts and Reasonings about God, Christ, heaven; and according to the age of the children observed. These papers must be of the greatest interest to the psychologist and the anthropologist.

The Hearing of Children. O. CHRISMAN. (Reprinted from the *Pedagogical Seminary*, Vol. II. No. 3, 1893), 45 pp. 8vo.

A *résumé* of all experiments upon the hearing of children by observers in various parts of the world. The only work giving a general idea of the labor done in this department of research.

Correlation of Mental and Physical Powers. J. VENN. *Monist* (Chicago), IV. (1893-'4), 5-19.

Based upon anthropometric tests of students at Cambridge, England, combined with standing in class-lists at examinations. Author holds that there is decided evidence in support of the view that bodily and mental excellence are independent of each other, and calls attention to the Hindoo scholars in support of this contention.

Ueber die geistige Ermüdung von Schulkindern. L. HÖPFNER. Ztschr. f. Psych. u. Phys. d. Sinnesorgane (Hamburg u. Leipzig), VI. (1893), 191-229.

The first part of this paper (191-203) is devoted to the consideration of the experiments and investigations of other observers,

especially Galton, Sikorski and Bürgerstein; part second to Höpfner's own observations on a class of some fifty boys, averaging nine years of age. The test consisted in the writing (which took up more than two hours) of nineteen sentences, averaging thirty words each, and part third (211-229) to a psychological analysis of the mistakes for the purpose of the study of fatigue.

Die Ferienkolonien in der Schweiz in den ersten, 15 Jahren ihrer Entwickelung, 1876-1890. A. MARTHALER. *Ibid.*, 473-489.

The first idea of children's colonies for health and pleasure was put forward by Pastor Bion in Zürich. An appeal to the public of that city resulted in the subscribing of 2,300 francs, and in 1876 three colonies, consisting of sixty-eight children, were sent from Zürich into the mountains of Appenzell. In 1878 Basel followed suit; in 1879, Aarau, Bern and Geneva; in 1880, Chur, Neuenburg and Schaffhausen; in 1881, Winterthur; in 1882, Euge bei Zürich; in 1883, St. Gallen; in 1884, Lausanne. Then there was a cessation until after the international congress of children's colonies held at Zürich in 1888, when two other towns, Biel and Töss, adopted the custom in 1889. The following table shows the growth of the movement since its inauguration:

	Number of Colonies.	Number of Conductors.	Number of Children.	Expenditures in Francs.
1876	3	10	68	2,361
1890	53	86	1,403	52,185

Die philosophische Bedeutung der Ethnologie. T. ACHELIS. Vierteljahrsschr. f. wissensch. Philos. (Leipzig), XVII. (1893), 286-311.

The author, the acknowledged German authority on ethnological jurisprudence, treats of ethnology in its relations to psychology, to the theory of knowledge, and to ethics.

Exhibit of Games in the Columbian Exposition. S. CULIN. *Journ. Amer. Folk-Lore* (Boston and New York), VI. (1893), 205-227.

In this paper Mr. Stewart Culin, of Philadelphia, gives an account of the exhibit of games (based upon the collection in the Museum of Archæology of the University of Pennsylvania, the result of two years' gathering) at the Columbian Exposition. The exhibit begins with puzzles and the simple games of children, and ends with complicated card games. Many interesting facts of invention and distribution are brought out.

The Pursuit of Happiness. D. G. BRINTON. A Book of Studies and Strowings. Philadelphia, 1893, XIV. 292 pp. 8vo.

Treats of the possibility of happiness, the definition of happiness, the relative value of pleasure, the distribution of happiness, self-education and the promotion of one's own happiness, bodily and mental constitutions, physical surroundings, luck and its laws, occupations of necessity and choice, money-making, pleasures of the senses, pleasures of the emotions, pleasures of the intellect, satisfaction of the religious sentiment, cultivation of individuality, safety, liberty, education, morality, duty, benevolence, business,

society, fellowship, comradeship and friendship, love, marriage and the family relations, the removal of unhappiness, the inseparable connection of pleasure and pain, the education of suffering. All these topics are written of in Dr. Brinton's best vein. The book is epigrammatic, entertaining, inspiring and excellent in point of literary style. Among the author's final words are these: "Thus, at the end of our wide wandering in pursuit of happiness, we look back and see that it is absent from nothing in life, not even from pain and sorrow; nay, that when all else has gone, when youth and health and fortune and love have left us, when we look forward despairingly to naught but loneliness and suffering, our very despair may prove to be divine, 'begotten by the finite upon the infinite,' and from its depths we may draw a rapture unknown to common pleasures, and taste the sweet waters of a bliss that is celestial." The "Pursuit of Happiness" is a book the reading of which is sure to take away some of the sting from the thought of Dante, so beautifully turned by Tennyson, "A sorrow's crown of sorrow is remembering happier things."

Der Blutaberglaube in der Menschheit, Blutmorde und Blutritus. H. L. STRACK. 4te, neu bearb. Aufl., München, 1892, XII. 155 S. 8vo.

This is a thorough study of superstitions and ceremonies connected with the use of blood, abounding in bibliographical and historical references. Among the topics considered are blood oaths; healing by blood; superstitious uses of blood and other parts of executed criminals, suicides, infants, etc.; human sacrifice, etc. The main portion of the book, however, is a scientific defense of the Jews against the horrible charges promulgated throughout Europe by the "Jew-baiters." Professor Strack's book is a valuable contribution to the history of religion and psychical perversion.

The Ethics of Tribal Society. E. P. EVANS. *Pop. Sci. Mo.* (New York), XLIV. (1893), 299-307.

A general discussion of the subject with reference chiefly to the Indo-European nations.

On the Delicacy of the Sense of Taste Among Indians. E. H. S. BAILEY. Kans. Univ. Quarterly, Vol. II. 1893, 95-98.

Results of tests on thirty-one boys and thirty-six girls, of from twelve to twenty-one years of age, at the Haskell Institute, Lawrence, Kansas. Also twenty-six males and twenty-six females, white, of about the same age as the Indians. The order of delicacy is about the same for the two races. The ability to detect the different substances when they are in very dilute solutions is less in the Indians. The males (of both races) seem able to detect a smaller quantity than the females. In other cases the females have the more delicate organ of taste.

Un Primo Passo alla Pedagogia Scientifica e la Carta Biografica. GIUSEPPE SERGI. Milano. Roma. Napoli. s.d. 35 pp. 8vo.

Professor Sergi is one of the educators and scientists who are striving to place pedagogy upon a scientific basis of observed facts and phenomena, and to have it proceed according to natural methods. In 1885 he instituted anthropo-psychological investigations in the Italian schools, after the manner of Galton; the pupils being examined on entering schools and when their course was completed. In the city of Rome alone, 2,500 pupils (of both sexes)

were thus examined, making a total of 250,000 separate items of observation. The present pamphlet enlarges upon the importance of such investigations, explains the methods and instruments employed, and gives the blanks to be filled up, but does not indicate the results obtained. Professor Sergi has discussed the same subject in his book, *Educazione ed Instruzione* (see *Pedagogical Seminary*, II. 473), from which this brochure seems to be a reprint.

B. Artistic and Æsthetical.

Evolution of the Æsthetic. W. H. Holmes. Proc. Amer. Ass. Adv. Sci., Vol. XLI. (1892), 239-255.

The address of the vice-president, section H of the American Association, is devoted to the study of the non-essential arts of man, the science of the beautiful, which has to deal with actual phenomena, with facts as hard, with principles as fixed, and laws as inflexible, as do the sciences of biology and of physics. Professor Holmes treats briefly of the æsthetics of the individual, of national and race culture evolution, and discusses the probable order of the development of the various æsthetic arts, which he thinks to be: painting, sculpture, architecture, music, poetry, the drama, romance and landscape gardening.

Indian Songs. Personal Studies of Indian Life. Alice C. Fletcher. *Century Illustr. Mag.* (New York), Vol. XLVII. (1893-'4), 421-431.

An investigation, by personal experience, of the general character of the music and poetry of the Siouan tribes, with whom the author is intimately acquainted. There are mystery songs, thunder songs, war songs, choral and historical songs, children's songs, lovers' songs, religious songs, etc. The musical instruments were the flute, whistle, drum, rattle. The following passage is worth remembering: "The native ear is precise as to time; a retard occurs only in the mystery, dream and love songs; in any other a variation of the value of a thirty-second or a sixty-fourth of a beat is sufficient to throw the tune out of gear to the Indian. Syncopation is common, and the ease with which an Indian will sing syncopated passages in three-four time to the two-four beat of the drum is remarkable. One of our own race could hardly do this without careful training and much practice. An Indian's ear is as keen for time as his eye for tracks in the forest."

C. Sociological (and related subjects).

Le Rire et la Liberté. A. Perijon. *Revue Philos.* (Paris), XVIII. (1893), 113-140.

Laughter is, in a general way, the sign of liberty—visible liberty, in fact, the *vis comica*, the sense of the ridiculous, the tendency to laugh, belong to every age, to every people; some have more, others less. M. Perijon writes interestingly of the sociological aspects of laughter.

La Logique sociale de Sentiments. G. Tarde. *Revue Philos.* (Paris), XVIII. (1893), 562-594.

A study of the social *Gefühl.* According to M. Tarde, the heart of society is a piano, which, from time to time, gets out of tune, and for centuries would fail to do full justice to any one if there did not appear at long intervals some tuner—apostle, founder of a religion, mystic, great popular reformer. When one of the chords

vibrates no longer, or is dissonant, society is ill. In the ages past, much progress has been made. To be sure, society has still its disturbances and its revolutions, but the old spirit of coterie and clanship with its bloody feuds has given place to the spirit of party, which is surely an advance towards social peace and quietude. The dialectic of social logic consists, therefore, in according and equilibrating the diverse or even antagonistic sentiments, and in substituting for them a system more stable by increasing the proportion of sympathetic sentiments at the expense of the antipathetic, which are bound up with them. The most general fact which the history of human society reveals to us is the continual increase of the social group in extent and in depth; family, tribe, city, state, federated dominion, mark the line of progress. The system of social logic tends ever to base itself upon a maximum of love and a minimum of hate. The author touches briefly on loyalty, democracy, war, glory, religion, social unions, national hatred, class hatred, domesticity, friendship, love, morality and urbanity, amusements, recreations, public festivals. Everywhere he sees the advance of that international spirit, that instinct of common desire, common ideas, common hopes, common beliefs, which are agitating humanity more and more as the years go by.

School Statistics and Morals. W. T. HARRIS. *School Review* (Ithaca), Vol. I. (1893), 218-225.

In this paper the United States commissioner of education tells us what the late census has to say of the relation of education to morals. Dr. Harris thinks that while the claim that the number of convicted criminals has increased must be allowed in face of the facts, the fostering of honesty, truth, temperance, fortitude, thrift, etc., in the schools has had a large share in producing the favorable moral and industrial conditions existing in the state giving the largest amount of schooling to each inhabitant.

Interesting from another point of view is W. Addis' paper: "Ten Years of Education in the United States," *Ibid.*, 339-353. Here statistics of taxation, salaries, attendance are considered.

The Psychological Basis of Social Economics. L. F. WARD. Proc. Amer. Ass. Adv. Sci., XLI. (1892), 301-321.

The author's conclusion is that "the advent with man of the thinking, knowing, foreseeing, calculating, designing, inventing and constructing faculty, which is wanting in lower creatures, repealed the biologic law or law of nature, and enacted in its stead the psychologic law, the law of mind." The old political economy is true only of irrational animals, and is altogether inapplicable to rational man.

The Relation of Economic Study to Public and Private Charity. J. MAVOR. Annals Amer. Acad. Polit. a. Soc. Sci. (Phila.), IV. (1893), 34-60.

This is the inaugural address of the new professor of political science in the University of Toronto. Professor Mavor discusses at some length Le Play, who, in 1829, began the series of family monographs, and General Booth, whose life and labors amongst the poor of London are called upon for many illustrations. The use of economic students lies in their investigation and interpretation of conditions and facts. What we need in the study of economics to avail us in practical affairs is insight, insight, and always insight. It should not be said: "You are disobeying the

laws of political economy," but "You are disregarding the lessons of history"—it is mainly from disregarding the plain lessons of history, frequently from ignorance of these, that men go wrong in political action.

L'Education Nationale. FRANCK D'AVERT. Rev. intern. de l'Enseignem., 13me Année (1893), 308-320.

National education, says the author, is education given by the nation; its nature, its sphere, are vast problems of public pedagogy, requiring careful investigation. To arouse and to develop the national conscience in the child is a species of education which belongs peculiarly to the state, and to the state alone. At his birth three concentric circles surround the child—the family, the church, the state. Between the family education, which forms the "enfant de la maison," and the moral (religious or lay) education, which makes of the child a member of humanity, comes necessarily the national education, which makes of the individual a citizen. This last the state alone is fit to give. Upon this topic M. d'Avert writes the rest of his article.

Anthropometry as Applied to Social and Economic Questions. C. ROBERTS. *Humanitarian* (London), III. (1893), 422-429.

After referring to the anthropometric investigations of various races, of children and the sexes at various ages, etc., Dr. Roberts treats of the application of anthropometry socially and economically—the endeavor to determine whether England is stationary, improving, or degenerating physically; the physical conditions of the various classes, etc. The government returns show during the forty years from 1833 to 1873 a decided gain in stature and weight of factory children; the physical condition of men offering as recruits has greatly improved; while the statistics of the Friends' School at York, extending over twenty-seven consecutive years, indicates a like improvement in the better classes of the population.

Geschichte des Armenwesens im Kanton Bern von der Reformation bis auf die neuere Zeit. KARL GEISER. Ztschr. f. schweizerische Statistik (Bern), 29 Jahrg. (1893), 532-591.

A brief and interesting sketch of the condition of the poor and their relief in the last three centuries and a half in the canton of Bern.

A Study of Omaha Indian Music. By ALICE C. FLETCHER. Aided by Francis La Flesche. With a *Report on the Structural Peculiarities of the Music.* By J. C. FILLMORE, A. M. Archæological and Ethnological papers of the Peabody Museum, Harvard University, Vol. I. No. 5.

When first hearing Indian music, it is difficult to penetrate the noise and hear what the people are trying to express. The noise of their drum affects us as the hammers of the piano do an Indian when their songs are rendered thereon. Below the noise is finally discovered matter worthy of study and record. The first studies were crude and I was more inclined to distrust my ears than my theories. During the investigations, an illness came on. While attended by Indian friends, they would frequently sing softly and with no drum. The beauty and sweetness of the songs were thus revealed. The return of health was celebrated by customary ceremonies and music which bespoke the kind inner life of the Indian. Then I ceased to trouble about scales, rhythm, etc., and

trusted the accumulating facts. The songs of one tribe are frequently sung by others and those far distant, but they are always credited to the tribe to which they belong. Indians are not plagiarists. Among the Indians there is not a phase of life that does not find expression in song. Music is also the medium through which man holds communion with his soul and with the unseen powers which control his destiny.

Songs are handed down through generations of past events, and are retained only by memory. Unlike people who possess written music, and have a device by which a tone can be uniformly produced, the Indian has no pitch or uniform key for a song. It can be started on any suitable note and the intervals preserved. Those having good voices and memories are the music teachers. The Indian enjoys a tremolo and vibrations of the voice. In love songs and some others, he waves his hand to and fro from his mouth to produce pulsations. Comparatively few Indian songs are supplied with words, for they are taken apart and modified so as to make them more melodious. Rhythm of the music demands this. We seem here to come upon the beginnings of versification. We fail to find evidence of the sustained intellectual effort essential to the development of poetic art. Sounds that lend themselves easily to singing are used instead of words, but have no definite meaning. If a composer sets syllables to his song, they are preserved.

A collection of ninety-two songs is given with their music; some have syllables. They are of three groups: class, social and individual. They are very melodious when played and show how they permeated the avocations and beliefs of the Omahas. The accompanying instruments are the drum, rattle and whistle. The words giving only a hint, render it difficult for the unheralded melody to secure our attention before it is finished. These songs—the product of Indian tribal life—suggest the question whether sustained thinking, without which there can be no full expression of thought in music or any other art, is possible in a state of society where labor is not coördinated, where each person stands individually against hunger and mortal enemies. While it is true that evidences of sustained thinking are wanting, these songs show nascent art, both in poetry and music. Whenever one man yearns toward the mysterious unseen powers that environ him and seeks an expression of his personal loves, hopes, fears and griefs, his song will answer in its fundamental directive emotion to that of every other man. This is true of our folk-music, such as the "Mystery Songs," as compared with Indian songs. In comparison with our more modern music, the divergence is upon the intellectual rather than the emotional plane. Our music has gained power by its being written. The eye has reënforced the ear, developing a broader field for musical expression. It is noticeable that there are no labor or guild songs. These originated in a society where labor had become secularized, both in feeling and association, unlike the Indian who directs labor with supernatural influences. As the Omahas, as a tribe, have ceased to exist, and the young people are being educated in English, their directive emotion will hereafter take the lines of our artistic forms. Therefore there can be no speculation as to any future development of Omaha Indian music.

Structural Peculiarities of the Music.

Investigations covered the following points: 1. The scales on which Indian songs are built. 2. The harmonies naturally implied in the melodies of the songs. 3. The tonality of the songs as indi-

cated by melody and harmony combined. 4. Rhythms. 5. Phrasing and motivization. 6. Quality of tone and correctness of intonation. 7. The Indian flageolet.

It was found that: First. The five-toned major and minor scale was used; *i. e.*, the common scale with the fourth and seventh omitted. Second. The Indian was not satisfied with the melody when played without the addition of chords, and whatever was satisfactory to the primitive man was to the trained musician. Also in common with the trained musician, he accepts the common chord as a perfect concord. Third. The question of tonality was often difficult, not to say impossible, to decide from the melody tones alone. Several examples illustrating this are given. Fourth. One of the most notable rhythmic peculiarities of these songs is the grouping of pulses into measures of different lengths. Another is the mixture of twos and threes in the same measure. Rhythm is difficult, but the element most developed in music. Civilized music has not surpassed it. Fifth. There is a rich variety of phrasing. Their spontaneous expression of feeling in tones are within their limits artistic. Nature seems to have taught them "motivization," as our professors of composition teach their pupils. Sixth. Some of the melodies are beautiful. The general impression is that they are not so, on account of noise of accompanying instruments. The high pitch of the voices is distracting. The songs are the expression of excited feeling, and the singers are stirred up almost to frenzy. Strangers, too, have no idea of the meaning and spirit of the music. Many songs are the fervid expression of the Indian's most sacred beliefs and experiences. Much of the music is profound, high and ennobling, and the better it is known, the more this will be seen. If the deficiencies of Indian performance on the side of sensuous music were removed, and a beautiful quality of tone by orchestra or voice were secured, its impression would be improved. Though possibly the accessories are necessary. But these beautiful chorals will certainly always remain the expression of genuine religious feeling, and I doubt not their merit will be recognized. Seventh. The flageolet is a rude instrument of red cedar, evidently built "by guess."

The merits of Indian music consist, first, in an elaborate, well-developed rhythm; second, in fresh, original, clear, characteristic expression of the whole range of emotional experience of primitive people.

The problems presented in this study are two: First. The origin and function of the music. Second. The psychological, physical and acoustic laws, in accordance with which the musical phenomena have become what they are. In answer to the first: These songs had their origin in feeling, and their function is to express feeling. Second. The Indian song is an absolutely spontaneous natural product. What correlation of the mind with the auditory and vocal apparatus, and of these with physical laws of acoustics, determines the course of melody? This suggests numerous questions. For instance, why are melodies based on the five-toned scale? A possible solution is that the harmonic sense is universal. In the Indian the harmonic sense is latent, but his sense of a tonic chord and related harmonies is probably the same as ours. CORNELIA W. DRESSLAR.

Russian Folk-Songs. A Study in Musical Psychology. J. C. FILLMORE. *Music*, June, 1893.

The Russian folk-songs are wholly spontaneous; the natural product of the free, untrammeled impulses of human nature. The

musically uncultivated Russian, like other primitive men, regards his music as the expression of feeling, of moods and emotions. The national folk-songs reveal the national character. The perception of the musically uncultivated man is completely in agreement with that of the most highly trained musicians as regards the primary relation of music to feeling, its function as the natural means of expressing emotion, and the characteristic types it assumes.

The utmost that music can do, is to express so definitely the emotions naturally arising from an event that, when we are once given a clue, the feelings expressed may suggest the ideas which awaken the feelings. Unlike the primitive music of other races, that of the Russian has no five-toned scale. This is the common major scale with the fourth and seventh omitted. The complete diatonic major or minor scale is used. This implies a stage of development in advance of that in which songs are made up of five tones only, or a natural musical endowment superior to that of most primitive races. The development of the five-toned scale into an eight-toned one is explained, and different theories given. But the dual nature of harmony has not yet been proven.

The theory that the minor chord is due to our perception of the undertone series, depends primarily on the assumption that the minor chord is a perfect concord. Though it is commonly assumed to be so, the fact that the Indians, as well as Bach, will end a minor song with a major chord, will have to be otherwise explained. In singing the minor, he is guided by no preconceived theory. He freely expresses himself. One reason why his effort at spontaneous emotional expression should take on the shape of the successive tones of a minor chord, with a filling in of tones which imply the dominant and sub-dominant chords, is that the five-toned major scale is easy to sing, and the five-toned minor is not only as easy, but is made up of the same tones in the same order. In changing them from a major to a minor key, only the starting point is changed, and not the melody or harmony. Fourteen "Russian folk-songs" are given, including a "love song," "harvest song," "comic song," and others, in Great Russian and Little Russian (Cossack). All are supposed to be characteristic types, and to reveal the state of feeling which prompts each song. C. W. D.

II.—NEUROLOGY, MORBID PSYCHOLOGY, INSTINCT.

By Assistant Professor C. F. Hodge.

The Nerve Cell Considered as the Basis of Neurology. A. E. Schäfer. *Brain*, Vol. XVI. pp. 134-169. 18 Figs. in text. 1893.

An important point in the terminology of the subject is first to receive attention. In 1891 Waldeyer proposed the term neuron to designate the anatomical unit, cell-body with processes attached, of the nervous system. Schäfer insists that just as we include processes with the cell-body in all other tissues, so here the term nerve-cell should be held to its primitive meaning and cover body and processes. Waldeyer's term "neuron" Schäfer appropriates to designate the axis-cylinder process. Protoplasmic processes are given the appropriate name of dendrons. With these terms clear, it becomes possible again to classify nerve-cells intelligently. "All possess at least one neuron." They may be dendritic or adendritic,

mononeuric, dineuric or polyneuric. For the branches of neurons, Cajal's term, collaterals, is adopted. While thus distinguishing between these two kinds of processes, the author frankly states that "it is impossible to say positively that there is any essential difference between the neurons and dendrons." Neurons and dendrons end finally alike in terminal arborizations; and this fact is taken to support the view that the structure of the axis-cylinder is fibrillar. The length of a neuron before breaking up into its terminal arborization has proved serviceable for purposes of classification. Upon this distinction Golgi based his classification into "motor" and "sensory." Objections have accumulated against this classification to such an extent that the author deems it necessary to substitute for Golgi's cell of the first type projection-cell, and intermediary-cell for "central," or cell of the second type.

The more important views advanced in the paper may be gathered from an abbreviation of the seven conclusions: 1. "That every nerve-cell forms a structural element which is anatomically isolated from, but in physiological continuity with other nerve-cells." 2. "That the physiological continuity of these elements depends on the contiguity either of the ramified cell processes of different nerve-cells with one another or of the ramified processes of one cell with the body of another cell." 3. "That the same nerve-impulses do not necessarily pass from one element of a nerve-chain to the next, but that more probably new impulses (often of different rhythm) are generated in the successive elements of the chain." 4. The converse of 3. 5. "That either the body of the cell or any of its processes may be concerned both with the starting and with the transmission of nerve-impulses; and, that these may originate by acts of contraction, causing waves of pressure or variations of surface-tension to traverse the fibrils." 6. "That the body of the cell is especially concerned with presiding over the nutrition of the whole cell-element; this trophic function being intimately associated with the presence of the nucleus. Nevertheless nerve-impulses may both originate in and be conducted by the cell-body. The dendrons or protoplasmic processes, being extensions of the protoplasm of the cell, may primarily serve to assist in the nutritive processes, as was supposed by Golgi, but they undoubtedly also, like the cell-body itself, may in some cases convey nerve-impulses." A. 7. "That the ordinary centrifugal paths are blocked for centripetal impulses, although the centripetal paths may convey centrifugal impulses, this physiological difference being correlated with a difference of anatomical relationship at the junction of the respective cell-elements."

The figures are culled from best sources, new and old, from M. Schultze, Ranvier, Cajal, Retzius, Lenhossek; and these are supplemented by original diagrammatic compilations, which add clearness to the subject.

Zur Frage über den Bau der Nervenzellen und über das Verhältniss ihres axencylinder (Nerven) Fortsatzes zu den Protoplasmafortsätzen (Dendriten). A. S. Dogiel. *Archiv für Mikroscopische Anatomie*, Bd. 41, S. 62-87, Taf. IX. and X. Bonn, 1893.

Zur Frage über das Verhalten der Nervenzellen zu einander. A. S. Dogiel. Archiv für *Anatomie und Entwickelungeschichte*, 1893, S. 429-434, Taf. XVI.

These papers are the latest in a series of six which have appeared from the above writer since 1888. Their chief interest in the present connection attaches to the strong evidence which Dogiel has

been able to bring forward for the direct anatomical continuity of nerve-cells through their dendrons. Nerve-cells, as he finds them in a number of retinæ of different animals, are not isolated elements, as is generally taught at present, but cells usually of similar types are joined by their dendrons into cell-colonies. Further an axis-cylinder may arise in three ways: a, from the cell-body direct; b, from the network formed by branching of neurons; c, from the network of dendrons. The method employed, methyl blue staining, exhibits a difference between neurons and dendrons similar to that by the Golgi method. But since fibrillæ from these processes may unite to form an axis-cylinder, they must be unconditionally considered to be of "Nervennatur." Thus far the author's work has been confined to the retina; but there is no good reason for supposing that relations of cells are different here from their relations in other parts of the central nervous system. This work, therefore, if confirmed, must negative the accepted doctrine of isolated cell-elements.

A Physiological, Histological and Clinical Study of the Degeneration and Regeneration in Peripheral Nerve Fibers after Severance of Connections with the Nerve Centers. W. H. HOWELL AND G. C. HUBER. *Journal of Physiology*, Vol. XIII. 1893, pp. 335-406; Plates XII. to XVI.

The above paper was awarded a prize offered by the American Physiological Society for the best essay upon the subject. The chief object of the research was to test experimentally the possibility of "union by first intention" of a nerve severed from its central connections; together with a thorough study of histological steps in processes of degeneration and regeneration. Dogs were used in all but one experiment, which was made upon a rabbit, and the ulnar and median nerves were either cut, cut and sutured, crushed by a ligature, immediately loosened, or coagulated by contact with a tube, through which water at 80° was allowed to flow. The first result to be noted is that in no case did "union by first intention" take place. In all the experiments degeneration of the peripheral end was complete through its entire length. Certain authors have described experiments in which both sensory and motor functions became re-established in a severed nerve in a few hours. In these experiments the least time in which irritability began to return to parts peripheral to the cut is twenty-one days; and at this time regeneration is found to have progressed some distance beyond the wound. Sensory nerves regain function before motor. Both sensory and motor function is found to be imperfect at the end of seven weeks and nearly normal by the end of eleven weeks.

The histological evidence as to the processes concerned has been made quite complete and is well illustrated by seventy-six figures. This evidence favors the view that embryonic fibers form in the distal nerve and subsequently unite in the cicatrix with the axis-cylinder as it grows out from the central end.

Histogenesis of the Retina in Amblystoma and Necturus. F. MALL. *Journal of Morphology*, Vol. VIII. pp. 415-432; 12 Figs. 1893.

The above paper fills a long-felt need by giving in a brief form a clear orientation of the layers and elements of the retina. Two principles of universal application to the growth of nerve tissue are stated at the outset. These are: 1. "The primitive growing point of all vetebrate nerves is in the layer of cells on the outermost side of the ectoderm, and the axis of division is parallel

with the ectoderm." 2. "The direction of transmission of an impulse is already determined by the position of the cell in the ectoderm." That is, the receiving side of a cell is the one originally toward the surface, while the giving pole is turned toward the interior of the body. Under these principles, and keeping in mind the formation of cerebral and optic vesicles, primary and secondary, it is made perfectly clear why the optic nerve fibers should grow first toward the vitrious chamber and afterwards pierce the retina in order to reach the brain. This also explains the inversion of the rod and cone layer, these elements being the receiving poles and the line between them, and the pigment layer of the retina being the original external surface of the body. The well chosen cuts render this intricate problem doubly lucid.

On the Method of Transmission of the Impulse in Medullated Fibers. E. R. EDES. *Journal of Physiology*, Vol. XIII. p. 431.

Experiments described in this paper were made in the physiological laboratory of the Harvard Medical School under the direction of Dr. Bowditch, and results confirm in the main that author's previous work upon the non-fatigability of nerve fibers.

The method employed consists in using the action current as a measure of the nerve impulse. This is read by means of a delicate capillary electrometer. The muscle was retained, and although not used to measure the impulse, gave a fine comparison of muscle and nerve fatigue. This is expressed in two charts (p. 437), both of which show that the muscle tires rapidly for the first few minutes, then more slowly and finally very slowly ; the nerve on the other hand practically holds its own. Up to five hours' continuous stimulation, the action current suffered no diminution. That this is not true for longer periods was due to trouble with the electrometer. Experiments let run over night (11-14 hours) showed an action current of about one-fourth the original strength. According to Maschek, when such diminution occurs on cutting the nerve off so as to place a fresh cut section on the electrodes, the action current returned to normal. This was not the case with Edes' experiments. Herzen's strychnine experiments were also repeated on rabbits and frogs, the conclusion therefrom being, contrary to Herzen's, that the "exhaustion obtained could be located wholly in the muscle."

In a short addendum are summed up the results of a number of experiments made for the purpose of repeating Demoor's recent work upon the action of silver nitrate upon normal and exhausted nerve fibers. Demoor's statement is that "Frohmann's striations" are not found in exhausted nerves. The experiments of Edes gave the impression that stimulation "does make some *slight* difference in the behavior of the nerve fiber towards nitrate of silver."

Der Hund ohne Grosshirn. Siebente Abhandlung über die Verrichtung des Grosshirns. F. GOLTZ. Archiv. für die gesammte Physiol. Bonn, 1891, 2 Bd. LI. S. 570-614. 1 Taf.

This paper forms the strongest protest yet uttered against the doctrine of cerebral localization, so far at least as the dog is concerned.

Goltz gives us the results of removing the entire cerebral cortex (except a mere shaving of the inferior temporal lobes, left to protect the optic tracts) in three dogs. The first lived fifty-one days; the second, ninety-two days; the third lived eighteen and one-half months. In order to more fully meet the arguments of his opponents, the operations were performed with the knife.

Since results were uniform, mention of the third case will suffice. Upon June 27, 1889, the left hemisphere was removed. The right hemisphere was similarly excised a year later, June 17, 1890. The dog, in general, continued in good health, and was killed December 31, 1891.

Three days after the second operation, the dog could walk without help. Subsequent tests demonstrated that hearing was present in some degree, the animal being awakened by the blast of a horn. He also reacted to light, and was found to be sensitive to touch and pain in all parts of the body. Even the presence of smell, Goltz seems to consider, admits of question, since this could not be satisfactorily tested. The animal sneezed when tobacco smoke was blown in his face. He could taste, as was evinced by his refusing, with every expression of disgust, meat which had been rolled in quinine. The same meat was similarly rejected by his own dog on first tasting, but was subsequently gulped down "out of politeness." A brainless dog does lack politeness, as the author humorously adds.

Two points are of special interest to brain physiology in general. The first of these is that this dog required much shorter periods of rest or sleep than normal animals; and also became more quickly fatigued. This leads to the second point, which is that if over-excited or over-tired, the dog is likely to be thrown into a fit of epilepsy (p. 591). That an animal deprived of all motor cortex can exhibit typical epilepsy, is certainly revolutionary to post-Jacksonian ideas of the cause and origin of epileptic fits.

The brain was turned over to Schrader for examination and description. Dorsal and ventral views are given in the plate.

The Arrangement of the Sympathetic Nervous System, Based Chiefly on Observations upon Pilo-Motor Nerves. J. N. LANGLEY. *Journal of Physiology*, Vol. XV. pp. 176-244. Plates VII.-IX. Sept., 1893.

Reactions of the hair muscles are found to be of great service in determining the course of sympathetic fibers from the cord, through the sympathetic ganglia to their distribution in the skin. In brief this course is found to be the same as that of vasomotor and secretory fibers; viz., out of the cord by the spinal roots, through the white rami to the sympathetic ganglia, from this back to the spinal nerves, by the grey rami, and finally along with the cutaneous nerves to the skin. In the cord pilo-motor nerves are shown by properly graded stimulus to lie in the lateral columns; and their course out of the cord is entirely by the anterior roots. By the nicotin method, injection of ten milligrams into a vein, for the cat, it was demonstrated that all pilo-motor fibers are interrupted by cells in the sympathetic ganglia in passing through them to the skin. Distribution in the skin is found to coincide with that of the sensory nerves. It is unilateral, overlapping the mid-line very little, if at all; and successive grey rami supply successive sensory areas, generally quite sharply defined. A minute's description of relations of skin-areas to the different nerves is given for the cat, and the paper closes with deductions therefrom as to the arrangement of the sympathetic system in man.

On Disturbances of Sensation with Especial Reference to the Pain of Visceral Disease. HENRY HEAD. *Brain*, Vol. XVI. pp. 1-133. Plates I. and II. 42 illustrations in text. 1893.

A convenient paper for reference upon distribution of sensory nerves in the skin, aside from its main purpose. Areas for touch supplied by the spinal nerves have been shown by Sherrington to

overlap considerably; whereas, according to our author's observations, areas for pain, heat and cold do not overlap perceptibly. They correspond closely to the area of trophic influence supplied by each spinal nerve, these latter being indicated by areas of eruption in herpes zoster. In connection with disease of any visceral organ, disturbances of dermal sensations for pain and temperature are likely to arise over sharply defined areas. Pain in these cases is projected peripherally by allocheiria, *i. e.*, pain in an insensitive portion, *e. g.*, a viscus, being projected to a more sensitive part, the skin, supplied from the same segment of the spinal cord. The present paper deals with arrangement of nerves and skin-areas below the clavicles. The author promises a paper in the near future to cover the region of head and neck.

Untersuchungen über die Entwickelung der Area und Fovea centralis retinæ. J. H. CHIEVITZ. *Archiv für Anat. u. Entwickelungsgeschichte.* 1890, pp. 332-365. Plates XVIII.-XX.

Development of retinal elements, especially in the region of the area or fovea centralis, is outlined in four species of bird, viz., crow, finch, domestic pigeon and one of the gulls, *sterna cantiaca*, in one lizard, *lacerta vivipara*, and in a teleost, *sygnathus typhle*. The rabbit possesses no fovea proper, but an area centralis, "streifenförmig," which extends horizontally through the entire retina just below the entrance of the optic nerve. All the birds were found to have a central fovea well developed, and in the gull two foveas were demonstrated, a nasal and temporal, and in addition a "streifenförmige" fovea, which the author does not discuss. The lizard has no fovea, but a circular area centralis situated just above the optic pappilla. A "punctförmige" fovea was demonstrated in *sygnathus* located caudad of the optic papilla, somewhat nearer the papilla than the ora serrata. The greater part of the posterior half of the retina is modified into an expanded area centralis having the fovea in its center. The fovea assumes its special characters late in embryonic life.

Untersuchungen über den electrischen Leitungswiederstand der thierischen Gewebe. K. ALT, AND SCHMIDT. *Archiv f. d. ges. Physiol.* Bd. LIII. S. 575. Taf. 13.

Recent work upon this subject has given currency to the idea that the fluids contained in a nerve cause its electrical resistance to be about that of the blood or lymph. The above paper tends to bring us back to the notions of the physiologists who wrote before it was demonstrated, that a nerve impulse is not an electrical current.

The method employed consisted in placing a given length of tissue in the circuit, composed of semi-circles of zinc and copper; contact completing the circuit on the other side being made by a micrometer screw. The zinc arc was connected to a friction machine, the copper with a water-pipe. The electricity generated could thus go to ground either through the tissue or through the micrometer screw. By manipulating the screw it was thus possible to measure the length of the spark, and this was taken to indicate the resistance.

Results of experiments on a large number of organs are given in a table at the end of their article. The following figures are extracted:

Tissue.	Resistance.	Tissue.	Resistance.
Nerve	0.17	Brain	1.57
Muscle	1.00	Tendon	3.25
Blood	1.00	Bone	14.10
Skin	1.25		

The Industries of Animals. FRÉDÉRIC HOUSSAY. Pp. 258, 44 illustrations. London, 1893. English edition revised and enlarged with author's coöperation.

The especial *raison d'être* of this book lies in the parallellism which the author continually holds in mind between the industries of man and the industries of animals. Men placed before a given problem, the attainment of a definite end, have come to act in a certain way; before the same problem, animals from insects to apes proceed in much the same manner. Men hunt in ambush, dig pit-falls, arrange concealed traps; so do beetles, spiders, foxes and cats. Through the whole range of human activity the same is true. The sphere of action may be very small for any animal compared with that of man; but within this narrow sphere the animal solves his problems in general as man would under like circumstances.

What man does intelligently certain writers would insist animals do instinctively. But this distinction is breaking down on all sides. Houssay's view of the relation between instinct and intelligence is clearly expressed in a few words. Instinct cannot be regarded as the "rudiment of intelligence," as is often done. It is rather the essence of intelligence, intelligence "condensed and accumulated" from generation to generation. As actions laboriously learned become reflex and habitual with man, so do adaptations on the part of animals acquired by "reflection, sagacity and intelligence" become by natural selection the common stock of knowledge, the instincts of a species.

Animal industries are grouped under six heads, treated in as many chapters, beginning with the simplest and most primitive, "hunting, fishing, wars and expeditions," and closing with Chapter VII: "The defense and sanitation of dwellings." Chapter VIII is devoted to conclusions. The subjects relating to dwellings, provisions and domestic animals, rearing of young, of course receive their share of attention. Some striking instances are cited Of the many, I will note a single one (p. 49): An ant is observed to abandon its burden at the foot of a little hillock, over which she has tried in vain to lift it. She soon finds a comrade, also carrying a load; the two consult by means of their antennæ, and both start in the direction of the hillock. On reaching the spot, ant No. 2 lays down her burden, "and both together then seized a twig and introduced its end beneath the first load, which had been abandoned because of its weight. By acting on the free extremity of the twig they were able to use it exactly as a lever, and succeeded almost without trouble in passing their booty on to the other side of the little hillock." The above is given on the authority of Parseval-Deschênes, Paris, 1848. Many other examples are nearly as striking.

The key-note of the book is again struck in a concluding sentence. "The industries in which the talents of animals are exercised demonstrate that, under the same environment, animals have reacted in the same manner as man, and have formed the same combinations to protect themselves from cold or heat, to defend themselves against the attacks of enemies, and to ensure sufficient provision of food during those hard seasons of the year when the earth does not yield in abundance."

Ueber Gesichtsfeld-ermüdung und deren Beziehung zur concentrischen Gesichtsfeldeinschränkung bei Erkrankungen des Centralnervensystems. WILHELM KÖNIG. pp. 152, 13 Figs. Leipzig, 1893.

On the Physical Nature of Hysterical Unilateral Amblyopia and Sensitivo-sensorial Hemianæsthesia. BERNHEIM. *Brain*, 1893, pp. 181-90, 4 Figs.

On the Visual Path and Center. S. E. HENSCHEN. *Brain*, 1893, pp. 170-80.

A discussion of the psychical side of fatigues and defects of sight, which are usually ascribed to the optical mechanism, finds a suitable preface in the briefest possible outline of the cerebral tracts and centres concerned in vision. The present short paper by Henschen would seem to be the essence of this author's work, "Beiträge zur Pathologie des Gehirns," and may furnish such an outline so far as this field is concerned. The visual path is divided into three portions respectively: the frontal, optic nerves, chiasma and tracts; the middle, the ganglia of the brain-stem with which fibres of the optic tracts connect; and the occipital, the course of visual nerves in the cerebral hemispheres. In following this tangled mesh of connections a distinction must be made between "*visual*" fibers and "*optical*" fibers. Optical fibers serve as reflex paths, but have no visual function. Of the three great central ganglia into which the optic tracts flow, in the pulvinars and the anterior corpora quadrigemina, the external geniculate bodies, the last are "the main sight ganglia in man." This is the result of the author's analysis of clinical cases. Destruction of one external geniculate body invariably causes hemianopsia. The occipital portion of the visual path is more difficult to determine. Analysis of all clinical cases bearing on the subject leads Henschen to place the visual path in the "optic radiation of Gratiolet," in a bundle of fibers less than a centimeter thick, lying at the level of the second temporal gyrus and sulcus. Lesion of parietal lobes induces disturbances of vision only if this bundle be compressed,

The visual centre Henschen would limit to the calcarine fissure, which he would like to call the "cortical retina." Other portions of the occipital lobe so often and persistently included in the optical centre, possibly have functions closely associated with vision. Word blindness would indicate this. As to the organization of the visual centre, a single case, that of Hun, is taken to prove that the upper lip of the fissure represents the upper retinal quadrant. Clinical evidence is considered to support Wilbrand's conclusion that the macula is innervated by both hemispheres. Those afflicted with hemianopsia always retain vision at the point of fixation.

Bernheim demonstrated, in 1886, that subjects of hysterical or suggested amblyopia unconsciously neutralize their correct visual images by an act of mind. "They see with the bodily, not with the mental eye." A most instructive case by way of further demonstration is the one now reported, that of a youth of nineteen, who came out of an attack of influenza nearly hemianæsthetic on the left upper half of the body. Amblyopia of the left eye with dischromatopsia were prominent features. With this eye he cannot see a finger held before the face, and white and blue are called red; yellow, blue, and red, gray. Yet, with a prism held before the right eye, he sees two images, and tested with Snellen's (Stöben's modification) apparatus, he sees all six letters and recognizes their colors. Further, when sent to an oculist, whose glasses throw him off his guard, he is able to read perfectly well with the blind left eye alone. The visual fields are contracted, the left more than the right, as is usual in hysteria. A cure is sug-

gested and both return to nearly normal. The left ear and nostril were likewise affected and it was possible to show that here, too, the difficulty was altogether psychic. With eyes closed the patient could not find his left hand with his right. Hypnotized and given the suggestion that his right hand was a magnet, the hands came fairly together. All the above symptoms and tests demonstrate that all the disturbances of sensation, special and common, were of cerebral origin; "a disease of the conscious æsthesodic cells," is the way the author expresses it. Three weeks' psychical treatment restores all functions.

König's paper is, for the most part, a careful, detailed statement of clinical cases. For testing the fatigability of the visual field, he used Wilbrand's simplification of Förster's method, the perimeter tests being made only in the horizontal meridian. In all, seventy-four cases were examined, in which contraction or fatigue of visual field was demonstrated. The result of chief interest at present in the present connection is the conclusion which he reaches, viz., that visual fatigue is probably of retinal origin; while contraction of visual fields is to be considered, at least in a number of the cases, as depending upon functional disturbances of the cerebral cortex. This corresponds in the main with Wilbrand's results and with the findings of Pflüger and Schiele.

III.—EXPERIMENTAL.

On a Photometric Method which is Independent of Color. O. N. ROOD. American Journal of Science, XLVI. Sept. 1893, 173-176.

To determine the luminosity of a color in terms of gray or any other color by ordinary photometric methods is by no means easy, very slight differences in color making comparison more or less uncertain. The method proposed by Professor Rood has the advantage of great simplicity and does away entirely with the need of comparing the colors in the ordinary sense. It depends upon the observation that when a colored disk is combined on the color-top with an equally luminous gray disk, no flickering is to be seen, even with slow rotation, while, if a difference in luminosity of two, or even of one per cent., is present, a flicker can be detected. When the flicker is absent the colors blend in "a soft, streaky way." A test of the method, made by measuring separately six disks, (forming three complementary pairs) and calculating the brightness to be expected from combining them, and then actualyl making the combination, resulted as follows:

	Observed.	Calculated.	Difference.
Purple and green.	27.5	27.5	.0
Red and blue-green.	20.2	21.1	.9
Yellow and blue.	27.85	29.1	1.25

The method is equally applicable to comparing two colors or two grays. A considerable series of grays is necessary for making the original determination (the author used 100), but when a few standard disks of bright color have been accurately measured, other disks can be measured by matches built up with these standards and black and white. It is, as the author observes, "a matter of some interest in physiological optics to know that the sensation called 'flickering' is independent of wave length and connected with luminosity."

E. C. S.

Experimentelle Untersuchungen über die Helligkeit der Farben. EDUARD GRUBER. Wundt's Philos. Studien., IX. 1893, 429-446.

The method used by Gruber for determining the relative brightness of colors was the natural one of direct comparison, applied, however, in the form of the method of minimal change. Two color-tops, one carrying a gray disk, *i. e.*, a black and white one *(A)*, and the other a colored disk *(B)*, were set up before a dark background. The gray disk *(A)* was at first set decidedly too dark and gradually brightened till it seemed to the observer of equal brightness with the colored disk *(B)*. The condition of *A* was noted and then made much too light and gradually darkened till a match was again reached. The average of the two determinations, repeated several times on each side, gave the brightness of the color. The experiments made in this way, after a little practice, yielded excellent results, except in a few cases where the observers seem to have become habituated to a particular intensity of gray and to have judged by its return rather than by an unbiased comparison. For the special precautions employed the original must be consulted.

The author also investigated the Purkinje phenomenon and the effect of changes in saturation on brightness. The experiments on the first, so far as they went, gave results in accord with the similar experiments of Hillebrand. With decreased illumination, the blue and green not only lost less in brightness, as compared with the red and yellow, but less even than the neutral gray. The effect of change in saturation was tested by replacing a portion of the color on *A* by an equally luminous gray, but no change in the total brightness was to be observed. Experiments on a color-blind observer (red-green blind), made in the hope of deciding whether green appeared to him relatively brighter than it did to an observer with a normal eye, which might be expected on Hering's theory, unfortunately had to be discontinued before clear indications appeared. It is, perhaps, only fair to add that the same method of measuring the brightness of colors was used by Rood more than fifteen years ago; see *American Journal of Science*, Ser. 3, XV. 1878, 81-82. E. C. S.

On a Color System. O. N ROOD. American Journal of Science, Ser. 3, XLIV. 1892, 263-270.

In this article Professor Rood describes a method of working out a reproducible color system with the color-top, provided that there is at hand a single disk of known hue and power of saturation, *i. e.*, efficiency in the formation of gray when mixed with its complement. By combination with the standard disk, the power of saturation of its complement and of colors differing but slightly from that, are determined, and from these in turn the powers of saturation of other disks, till a considerable range in the color scale has thus been measured. When three colors widely enough separated to form the corners of a color triangle have been reached, such a triangle may be constructed in the usual way from the equation giving their mixture for gray, taking into account also their power of saturation, as already determined. This forms the basis of the system and other colors are assigned places in it in the usual way. For the details of the method and the discussion of the nature of the system thus constructed, the reader is referred to the original. The author unfortunately does not specify how the *hues* to be placed at the corners of this color triangle are to be selected, whether by reference to the spectrum, to well-known pigments, or in some other way—an omission that would have to be supplied before any-

one could exactly reproduce the color triangle described, though the author's generous offer of samples of colored paper with coefficients of saturation determined, might for the present supply this defect. E. C. S.

Eine neue Theorie der Lichtempfindungen. CHRISTINE LADD FRANKLIN. Zeitschrift für Psychologie, IV. 1892, 211-221. This paper is a full statement of matter presented in abstract at the International Congress of Experimental Psychology in London, 1892. The author's abstract will be found in the Proceedings of the Congress, pages 103-108, also in the *Johns Hopkins University Circulars*, June, 1893, and in *Science*, July 14, 1893.

On Theories of Light Sensation. CHRISTINE LADD FRANKLIN. Mind, Ser. 2, II. 1893, 473-489.

To propose a new theory for matters so long and carefully studied as those of physiological optics is a considerable feat, but one that Mrs. Franklin has accomplished with such success as to receive friendly notice in the address of the president of the British Association (*Nature*, Sept. 14, 1893, p. 469). The author's own abstracts are so accessible that no summary of her theory need be given here. Suffice it to say that, like all the better modern theories, it has been given a photochemical form. Two visual substances are assumed in the retina, one whose decomposition yields the stimulus for white (sensations of the black-gray-white series) and another whose decomposition is different for different kinds of light, giving by partial decomposition the stimuli for red, green and blue, and by complete decomposition the same decomposition-product as the first visual substance, and thus also the white sensation. How the theory fits with various classes of facts is set forth in the original, together with the chief difficulties in the current theories of Helmholtz and Hering. The theory most resembling this of Mrs. Franklin's is that of Donders, by whose this was in a measure suggested. Completeness is too much to expect in an account that the author herself regards as tentative, and some gaps may have been purposely left to be filled hereafter. Something certainly should be said with reference to black, and the explanation of simultaneous contrast will need radical revision.[1] A great advantage of the theory is that it makes the phenomenon of complementary colors a matter of retinal chemistry, instead of a matter of mingled sensations or of opposing anabolic and katabolic processes. Its assumption of three primary colors enables it also to avoid the difficulties that color-blindness offers to four-color theories. E. C. S.

Grundzüge der Physiologischen Psychologie. WILHELM WUNDT. Vierte umgearbeitete Auflage. Engelmann, Leipzig, 1893. Two vols., pp. xvi. 600, and xii. 684.

In this fourth edition, Wundt's standard work has received a general revision and an increase of nearly 180 pages, of which two-thirds is in the second volume. The main changes specified by the author, aside from such as were needed to bring the work abreast of present information, have been in the way of greater explicitness in the description of psycho-physiological methods and apparatus, and many new cuts of apparatus have been added. These changes will make the work more neccessary than ever to the many laboratories now getting under way. The value and convenience of the

[1] The reviewer understands that this matter has already received the author's attention.

new edition would have been increased if the parts newly added had been indicated, as in the new edition of Helmholtz's Optik.

Experimentelle Beiträge zur Untersuchung des Gedächtnisses. Von G. E. MÜLLER und F. SCHUMANN. Zeitschrift f. Psy. u. Phys. d. Sinnesorgane. Bd. VI. 2, 3, 4 and 5. 1893, 192 pages.

According to the modest statement of the authors, the aim of these series of experiments, which have been made at intervals from 1887 to 1892 inclusive, is not so much to add a number of important and interesting facts to the science of memory as to test and develop the experimental method introduced by Ebbinghaus.

While it is perhaps possible to summarize briefly the numerical results obtained, only a slight suggestion can be given of the praiseworthy spirit of experimental carefulness and thorough criticism in which the work has been done. The original must be referred to also for all details, since only the general plan can be mentioned. There are in all thirteen series of experiments, each usually extending over several months.

The procedure in the first two experiments resembles that of Ebbinghaus, except that the syllables are read off through a slit from a revolving drum, and that the experimenter and the subject are different persons. This mode of presenting the syllables was retained to the end and has the advantage of permitting only one syllable to be seen at a time, so that we have to deal with successive association exclusively. The rate with which they are presented can be easily regulated and the experimenter controls the correctness of the repetitions. Certain irregularities were observed in the nonsense material, and a new plan of constructing it devised for subsequent experiments.

The seventeen initial and twelve end consonants, and the twelve vowels and diphthongs used were written on cards and placed in three boxes. A syllable was made by taking one card haphazard from each box. Since they only used twelve syllable series, this method enabled them to construct what they call normal series, each of which has the following properties: All initial and end consonants and vowels are different. The initial consonant is not the same as the end consonant of the preceding syllable, or the end consonant of the second syllable of the same measure. Successive syllables do not form familiar words. Repetition of the same syllable is avoided till after a considerable time. All series, whether original or derived, are normal. Various ingenious devices make the otherwise laborious task of bringing this about comparatively easy.

The number of readings required for the first correct repetition is taken as the measure of the work done.

The central value as well as the arithmetical average are given for any given set of observations. The errors of psychological measurements are asymmetrical with respect to the average. There is much greater possibility of making large positive than large negative errors. The central value, which represents that number in a series of observations above and below which an equal number of records is to be found, is accordingly smaller than the average and represents more nearly the most probable observation.

Experiments I. to V.—A series of nonsense syllables is naturally read in a certain rhythm, preferably trochaic. The problem of the experiment was to see whether the associative bond was stronger between syllables of the same measure than between the adjacent syllables of different measures.

Except in the first two experiments, which were preliminary, a careful allowance is made for the various factors which might influence the rate, such as practice, fatigue, unconscious association, position, and interference of association.

This was done by learning comparison series which are influenced by all the factors the test series are, except the one to be tested.

In experiments III., IV. and V., six new or original series were learned each day, and the six derived series constructed from them were learned after twenty-four hours.

The derived series consisted of two comparison series, two series made up of couples belonging to the same measure, and two of couples belonging to different measures. The result shows that the association between syllables of the same measure is decidedly stronger than between adjacent members of different measures, but that there is a weak association in the latter case also. The experiments were made upon the authors and two other subjects. Subject M. gives the following central values: comparison series, 16.4; series with couples of the same measure, 11; of different measures, 14.5.

Experiment VI. was undertaken to study the strength of association between two syllables separated by a third from one another. Ebbinghaus' results showed that the associative bond extended not only to the next, but to the 2, 3, 4 and 8″ syllables. The writers doubt the validity of Ebbinghaus' conclusion that association extends to the 8″, since the small saving of 3.3% may be accounted for by some of the factors which influence the rate of learning, like unconscious preparation and association, or the absolute position of the syllables. Their method excludes Münsterberg's objection that these associations might be due to simultaneous impressions, since only one syllable is seen at a time. The derived series differed from those of Ebbinghaus, which had the syllables to be tested adjacent. Every other syllable of the original series was removed and a new one put in its place, in one case the odd or accented, in the other the unaccented. The result of the experiment is, on the whole, not satisfactory, since the comparison series are not in every respect but the one to be tested equivalent to the test series, but have less positions in common with the original series than these. The conclusion that there exists an association of measurable strength between every other syllable of a series once learned is, however, quite probable. Subject S. gives the following result: comparison series, 14.2; test series, 12.1 and 12.3 for accented and unaccented syllables respectively.

Experiment VII. shows that the absolute position of a syllable in a series has an associative tendency. For subject H.: comparison series, 9.6; test series, 7.7. As before, the syllables of the test series have the property to be tested; while it has been excluded from the comparison series.

Experiment VIII. shows that learning series with an iambic rhythm takes longer than with the trochaic; and that relearning a series takes longer with a different than with the same rhythm.

Subject H.: original series trochaic, 18.5; iambic, 20.; in relearning, trochaic after trochaic, 7.8; iambic after trochaic, 10.; trochaic after iambic, 9.; iambic after iambic, 7.4.

Experiment IX. tests the question whether there is an association from a syllable to the one immediately preceding it.

Only syllables belonging to the same measure were tested. Ebbinghaus, it will be remembered, found a saving of 12.4%, due to the association of a syllable with the one immediately, and 5% to the one second preceding in a sixteen syllables series relearned after twenty-four hours.

Subject Sch. gives for comparison series, 13.5; for test series, 12.5. There is therefore a slight backward association. As the authors remark, this may be due to the fact that the two syllables of a measure are treated by the mind as a group.

Experiments X. and XI. were designed to test Ebbinghaus' hypothesis that association of syllables can take place when they are simply stimulated in the proper order without actually appearing in consciousness. The saving in time he found in learning the second of two derived series when its syllables had been suggested in their proper order by the first, might be due to a certain preparation and not to actual association. There is a small probability that there is actual unconscious association.

Subject M. gives for comparison series, 13.62; for test series, 13.12.

Experiment XII. is concerned with the interference of associations, but gives no definite results and the work is still in progress. General observation seems to show that it is an influence of considerable importance, especially in learning new series.

According to experiment XIII. the first and second half of a series are learned equally well. A recent objection to the method, that repetitions and readings can't very well be coördinated is not valid, since the first part, which receives relatively more repetitions, is not learned either better or worse.

The authors call attention to the importance of rhythmic grouping for retention. The mind treats the syllables as units and their combination into measures as units of higher order. These again seem to be divided by cæsural pauses into groups of still higher order. The experiments may be taken as a demonstration of the common assertion that words are known as wholes.

There are several other matters of interest which space will not permit us to enter upon, such as the discussion of individual characteristics of memory, the tests for the various types, and the function of attention in such experiments.

BERGSTRÖM.

Über die Beeinflussung einfacher psychischer vorgänge durch einige Arzeneimittel. DR. EMIL KRAEPLIN. 1892, 258 pages.

In this book the author summarizes the results of his well-known investigations, which were begun in Wundt's laboratory in 1882, upon the influence of drugs on mental processes, and gives an account of some later experiments by improved methods. The discussion is very full, since the aim is not simply to present certain data, but to develop an experimental method for the study of these and similar questions. The introductory chapter on methods is accordingly of great interest. The measurement of mental processes is especially liable to error. Not only does the general mental and physical condition influence the results, but fatigue and practice cause variations in the tests themselves. Such sources of error can only be taken into account by the most careful criticism and laborious repetitions of the experiments.

The chronoscope or "intermittent" method of studying mental processes, which was employed exclusively in the older experiments, is used in the later only where the aim is to study the qualitative as well as the quantitative changes of associations. With this exception, the continuous method was used in all the recent experiments and gives by far the most satisfactory results. It was first employed by Oehrn, at the suggestion of Prof. Kraeplin, for studying individual differences in rate, practice and fatigue. The subjects in the recent experiments with alcohol and tea were, with one exception, the same as those for Oehrn's

experiments. The normal records obtained in the latter are used for comparison with those obtained under the influence of drugs. The tests employed were reading, adding and learning twelve-place numbers. The subjects read, added or learned, two hours continuously, marking off every five minutes the amount done. The averages of the records for every fifteen minutes, give the picture of the changes the processes undergo. In some experiments twenty, in others thirty, grams of alcohol were taken at the end of the first half-hour. The changes afterwards in comparison with the records of the first half-hour and those of the normal series are attributed to the influence of the drugs.

The Hipp chronoscope proved to be the most serviceable for the intermittent experiments. In the later experiments upon association time, lip keys were used by both experimenter and subject, instead of Trautscholdt's method of making and breaking the circuit by hand simultaneously with the pronunciation of the word.

An important departure is made in the mathematical treatment of the results. Even the older protocols are worked over and presented in the new way. The arithmetical average is no longer, as in the earlier experiments, given as the most probable value of a group of observations, but rather the middle or central record. In the still later publication of Müller and Schumann upon memory, it will be observed that the middle record is also preferred. The reasons for substituting it for the arithmetical average in the treatment of psychometric observations seem on the whole well founded. The middle record is much less than the average disturbed by accidental influences, which, as is well known, have much greater power to lengthen than shorten records. The central zone, in which one-half the observations fall, cannot, as in the case of the average, be represented by the usual probable error with its double sign, but by two unequal values with different signs. These are found by subtracting the middle value of the whole group from the middle value of the upper and lower halves respectively.

Aside from the determination of the variability and sensory or motor character of mental work, the only way at present of studying the qualitative changes of mental processes is by classifying associations. The difficulties are very great. The rubrics chosen were: outer associations, including those of co-existence, sound and habitual expressions; and inner or logical. Practice will in a short time change cases of the second type into those of the first.

The later experiments are concerned chiefly with alcohol and tea.

The data for the study of alcohol comprise twenty-seven early experiments, ten each for simple and adaptive reactions, and seven for reactions with discrimination; three early series of association experiments and seventeen later ones. To these must be added twenty-seven experiments by the continuous method with seven subjects, ten each for adding and learning, and seven for reading. A few tests were also made with Ejner's time-estimating experiment and the dynamometer. From seven and a half to sixty grams of alcohol were given as doses.

The experiments with tea are about as numerous and were made in much the same way. With the exception of a few association lists, the experiments with other drugs belong to the early period of the work.

Small doses of alcohol have a stimulating effect upon reaction time, reading, and in some cases on the learning of the number series. This begins shortly after taking the dose and lasts twenty or thirty minutes, and is followed by a depression, or lengthening of

the records. Even in small doses it has a depressing effect at once upon adding and usually upon association; and in large doses, upon all the processes. The contrast in the effect of alcohol is greatest between simple reaction and reading, on the one hand, and reactions with discriminations and adding on the other. The other mental operations occupy an intermediate position, for some subjects showing acceleration, for others a depression. The two sharply contrasted classes contain the one, sensory and intellectual; the other, motor processes. The clue to the understanding of the results is the distinction between sensory and motor modes of reaction. Sensory and intellectual processes are depressed, but motor stimulated. The different results in learning number series are to be explained by the fact that it is a motor process for some and a sensory one for others. The dynamometer record is of the latter type, so only the rate and not the strength of movement is accelerated. The effect of tea is nearly the reverse. It stimulates the sensory and intellectual processes and depresses the motor slightly. The influence of ten grams of tea shows itself for about an hour. The effect of the other drugs differs greatly from that of these two in degree and duration, but otherwise the effect of morphine (.01 grams) is like that of tea; and the effect of small doses of ether, amylnitrite, chloroform and paraldehyde is like that of alcohol. An increase of sensory or intellectual activity is always accompanied by a motor depression. The author suggests this may be due either to a selective chemical effect of the drugs upon the parts of the nervous system connected with the sensory and motor functions, or it may be due to the removal of physiological inhibitions by the depression of the higher centres. The author's interpretation of his results is beautifully illustrated by the chart at the end of the volume. Since the curves do not stand for any special experiment, the choice of ordinates is of course somewhat arbitrary.

BERGSTRÖM.

Studies from the Yale Psychological Laboratory. Edited by E. W. SCRIPTURE, PH. D. Instructor in experimental psychology. Oct., 1893.

These studies are the results of the first year's work in the Yale laboratory established and directed by Dr. Scripture. The work includes the following studies:

1. *Investigations in reaction-time and attention*, by C. B. Bliss, Ph. D. 2. *On monocular accommodation-time*, by C. E. Seashore. 3. *On the relation of reaction-time to variations in intensity and pitch of the stimulus*, by M. D. Slattery, M. D. 4. *Experiments on the musical sensitiveness of school children*, by J. A. Gilbert. 5. *A new reaction-key and the time of voluntary movement*, by E. W. Scripture and John M. More. 6. *Drawing a straight line; a study in experimental didactics*, by E. W. Scripture and C. S. Lyman. 7. *Some new psychological apparatus*, by E. W. Scripture.

The conclusions reached in the first part of the first study were: 1. No difference in reaction-time was found when the color of the light present in the field of vision was changed. 2. No difference was found in the times of reactions in the dark and those made while looking at a stationary incandescent light of six candle-power. 3. With the light in motion, the reaction-time was lengthened. 4. No difference was detected between the times of reactions in silence and those made while listening to the steady sound of a tuning-fork making 250 vibrations per second. 5. When the intermittent sound of a metronome was substituted for the fork, the time for reactions was lengthened. 6. The reaction to a sound heard in both ears is

shorter than when the sound is heard only in one ear, even after making allowance for the difference in intensity.

The second part took up introspective observation on reactions. The results obtained here were: 1. Reaction-time is constantly affected by irregular disturbance, a large part of which may be detected by introspection. 2. Introspection is not to be trusted in estimating results. 3. Exercise shortens reaction-time. 4. Reactions to the wrong signal, reactions before the signal is heard, and the reflex nature of reactions, are not sufficient criteria to distinguish muscular from sensorial reactions. 5. There are, at least, six distinct kinds of voluntary attention: ideational attention, neural attention, feeling attention, muscular attention, preparatory attention and inattention. 6. The involuntary attention is constantly changing.

In this second part, besides noting some misquotations wholly inexcusable, the reader comes to the general feeling that the results of introspection and experimentation are unscientifically blended. One, wonders, too at such a statement as the following: "A sixth state of the attention, one which requires as much effort of a certain kind as any, is that of inattention." By this is meant a voluntary turning away of the attention from *one* thing to *another*. Or, as in this case, voluntary muscular relaxation.

Mr. Seashore found that: 1. Within certain limits the accommodation-time varies with the distance between the points for which the eye is to be accommodated. 2. It takes longer to change the accommodation from near to far than from far to near, and this difference in time varies directly with the length of the accommodation-time. 3. For equal distances in the same range the accommodation-time is greatest for points near the eye and decreases with the distance of the points from the eye.

Experiments with electrical stimulus applied to the skin show that the reaction-time decreases with the increase of the stimulus.

Dr. Slattery came to the following conclusions for reactions to tones: 1. The law that the reaction-time decreases with increasing stimulus does not hold for hearing, and the reaction-times for tones of moderate intensity are about the same. 2. The longer time registered by some for very weak tones is probably caused by hesitations as to the actual hearing of the stimulus. 3. The reaction-time to tones decreases as the pitch rises. 4. The view held by Exner, Von Kries and Auerbach and rejected by Martins, namely, that about ten vibrations are necessary to the perception of a tone, no matter what its pitch, is sufficient to explain the differences in the reaction-times for different tones.

The most suggestive and interesting of these studies is the one by Mr. Gilbert, to determine the sensitiveness of children to changes in the pitch of the tone $\bar{a} = 435$ of international pitch. For this purpose a clever instrument was devised from a pitch-pipe whose reed was fitted with a sliding clamp. Five boys and five girls were tested for each age from six to sixteen and five girls for each of eighteen and nineteen. From these tests Mr. Gilbert came to the conclusion that "the least sensitiveness occurs with children of six years, where the average least perceptible difference is $\frac{3}{4}$ of a tone, and that as age increases the sensitiveness increases, although marked irregularities in this general increase was noticed at ten and fifteen years. The decrease in sensitiveness at these periods the author thinks is probably due, the former to second teething and the latter to puberty."

Dr. Scripture and Mr. Lyman found that in "ten boys of the average age of thirteen years of the upper grammar grade" for

drawing a straight line between two dots 100 mm. apart, "the facing position is more favorable for horizontal and vertical lines than it is for inclined lines. The right side position is also more favorable for horizontal and vertical lines than for lines at 45°. Holding the pencil far from the point is in general the most accurate method; near the point is as accurate as the middle grip."

To understand the apparatus described in the other articles, the reader is referred to the original, where they are illustrated and adequately described.

F. B. D.

L'audition Colorée et les Phénomenès Similaires. Communications de MM. FRANCIS GALTON et EDOUARD GRÜBER.

The results of the investigations set forth in this paper were read at the Congress of Experimental Psycholgy at London, 1892. After giving a table of the "chromatisms and photisms of the senses," the results of investigations concerning colored auditions is taken more at length, and especially that of the speaking voice. The subject experimented on heard *a* as pure white; *e*, yellow; *i*, blue; *o*, very black; *u (ou)* black; *ă*, brown, and *ĭ*, gray, approaching black. The same thing occurred for the consonants, except at the moment of hearing, the subject perceived two colors; one, the color of the consonant, and the other, a slight ray corresponding to the vowel used in speaking the name of the consonant. For example *f* (*ef*), is accompanied with the perception of a reddish-brown and a slight orange tint on the front side. This orange tint, the author thinks is due to the influence on the usual color (yellow) of *e*, of the reddish-brown of the letter *f*. This leads to the attempt to separate the vowel sounds from the consonants. The facts stated in this paper are very interesting, but perhaps not as important as the author thinks when he says: "These facts are of very great importance; they touch almost all the great problems of contemporaneous psychology. Moreover, they show a new path for crossing the field of the spiritually unknown, and give us a superior means of analysis." F. B. D.

Die bewusste Beziehung zwischen Vorstellungen als konstitutives Bewusstseinselement. Ein Beitrag zur Psychologie der Denkerscheinungen. Von DR. E. SCHRADER. Leipzig, Verlag von Duncker und Humblot, 1893, pp. xii., 84.

This pamphlet is the first of a proposed series of works upon judgment; more accurately, upon the place of the consideration of judgment in psychology and logic. I propose to devote some space to its criticism, since the author is making a serious attempt to answer a real and difficult question.

I may say at once that I do not regard the word "judgment" as a psychological, but only as a logical term. The psychological correlate of a judgment is an association or an apperceptive combination. I should, therefore, demur to the phrase "psychology of judgment" upon methodological grounds. The writer renounces it in favor of "psychology of conscious relation," for the reason that this is the more comprehensive expression—including judgments which are and judgments which are not formulated in language. But the confusion remains: a "relation" in psychology is just an association; relating is the logical way of marking associability (cf. preface, p. vi.).—A second point touched on in the preface is the relation of the association-psychology to psychology in general. While Dr. Schrader rightly refuses with decision to equate the two, he still

appears to lay too great a stress on the association-doctrine. The laws of association are coming to be more and more regarded in the way in which Aristotle regarded them,—as practical hints towards method, not as universal psychological uniformities. The notion of "association" itself has been divided up into those of "fusion" and "combination" or association proper; and we know far more of the former—new as the concept is—than we do of the latter. How much content is there in the association-doctrine of modern psychology? And how much exactness (p. viii.) attaches to the majority of extant association-experiments?

The introduction contains two sections. The first defines or describes "apperception," a term which the author uses in Erdmann's, *i. e.*, practically, in Herbart's sense. A special critique of Wundt's view is promised. The second deals with the limits of the individual perception-idea. Its unity is a functional unity. The discussion shows (p. 4) a want of acquaintance with Külpe's work (*Zur Lehre vom Willen, etc.*). Chapter I. gives instances of judgment-like processes (Sigwart), and analyzes them into (1) ideas of perception and movement, and (2) reproduced ideas. The general problem of the idea itself (its apperceptive constituents, in Wundt's terminology), and the special one of the movement-idea, are not touched upon. Chapter II. opens with an attempt at the associative explanation of these processes. It is found unsuccessful. But the attempt can hardly be more satisfactory to the associationists than the foregoing analysis would be to the (Wundtian) apperceptionist. Not only has the author tied himself down to his own analysis, and so missed certain associative moments which an opponent would at once urge; he also speaks throughout in terms of the particular association, neglecting entirely the important process of general reproduction. He himself proposes three further experiments. [(1) Can the instances be explained on the assumption that their analysis was incomplete? This is negatived. (2) On the assumption that several of the previous ideas exercise in common a reproductive effect? Yes; if we accept Wundt's active apperception. Only partially, if we do not. (3) On the assumption of very highly complex ideas? (Constellation-unit.) Only partially.] Similar remarks apply to these: the associationist could find a ready answer to the objections raised. The proof of a constituent of consciousness other than the sensation (as basis of the associating idea) must, it is true, be looked for in the first place analytically. But why start with so complex a process as that of (technical) association? Rather is it advisable to analyze idea, impulse, attention. Then, if the non-sensational element be found, we can proceed synthetically to put it into the more complicated concrete processes in which it can belong, not caring for any charge of multiplication of entities. For this is the essence of the matter: the associationist says, "I find in this complex process only associated ideas;" his opponent says, "I find in it something more." It is introspection against introspection. What remains but a shifting of the ground to simpler processes? The result of their investigation may be a similar divergence, but, at any rate, the issue becomes so far clearer.

Chapter III. deals with conscious relation as a constitutive element of consciousness; the modification of the signification of "consciousness," which its introduction entails, and its character as positive or negative. It is a little hard that neither Herbert Spencer's doctrine[1] of the composition of mind, nor James' view

[1]On p. 64 Spencer is mentioned, but the author's statement is dogmatic, and no references are given. There can, I think, be little doubt that Spencer's "relation" vacillates between *Beziehung* and *Verbindung*, and that it is not exclusively the equivalent of the latter term.

of the psychology of relation, finds mention. As for the exposition itself, I can only refer the reader to it. I hold in opposition to Dr. Schrader that the "relation" is logical, not psychological, but that it *can* be ideated (pp. 37 ff.), as every concept can. It is impossible here to justify this view at the necessary length.

In Chapter IV. is treated the relation between conscious relation and association. Association assists and prepares the way for relation; it is determined by the relation, and the latter is, in cases, resolved by it. In other words, the conscious relation stands to association very much as Wundt's apperceptive combination stands to it. Chapter V. discusses the views of some other psychologists: (1) Of the Herbartians and Münsterberg (doctrine of inhibition of ideas); (2) of von Hartsen; (3) of Stumpf (doctrine of relativity). Chapter VI. asks whether the conscious relation can serve to explain judgment. This question will be fully answered in the author's forthcoming *Analyse des Urtheils*.

If we take exception to Chapter III., it is unnecessary to criticise the superstructure raised upon it. While (as already said) I am in almost complete disagreement with Dr. Schrader on many points, I believe that his work is an honest effort to clarify our notions of the relation in which logic and psychology stand to one another. His further publications cannot but be interesting. E. B. T.

Warum müssen wir schlafen? Eine neue Theorie des Schlafes. DR. MED. EMANUEL ROSENBAUM. 1892, 58 pages.

The new theory is to be classed with those which attribute fatigue and sleep chiefly to the toxic products formed during activity. The author endeavors to show that the phenomena of sleep can be accounted for by the formation in the nervous system, and deficient elimination, of water, which is to be looked upon as a noxious waste product.

The theory is introduced by a synopsis of some of the facts of nervous and muscular activity and a sketch of the various theories of sleep from the time of Alkmæon, 585 B. C., to the present. The reference to current theories is, however, very meager, and only that of Preyer is mentioned.

The new theory finds its support in a study of the anatomical conditions of the nervous system in diseases like scarlet fever, abdominal typhus, acute atrophy of the liver, meningitis tuberculosa, etc., which are characterized by a tendency to sleep.

The symptoms and anatomical details are taken from Ziemesson's hand-book. In all cases there is a dropsical condition of the nervous system to which the author attributes the mental disturbances, especially the abnormal tendency to sleep.

Another line of evidence is found in the statements of Schiff, Harless and Ranke, that the excitability of a nerve diminishes with the increase of water in it.

As to the source of the water, some may exude from the veins and arteries, but it comes chiefly from the chemical changes in the tissues. The water eliminated by the kidneys and sweat glands comes from the arterial, that of the lungs from the venous blood. The amount of aqueous vapor exhaled is not affected by the amount taken into the stomach, but by the amount of work done. The venous blood carries away the water formed by oxydation in the tissue metabolism. The principle of hydrodiffusion applies to its elimination. The percentage of water in the venous blood is less than in the tissues, hence they will be drained by it. The water removed by respiration is the only part of interest for the theory.

A study of the tables of Pettenkoffer and Voit shows that more water relatively to the amount of oxygen inhaled is expired during the night than during the day. The conclusion is drawn that elimination does not keep pace with formation, and that muscles must rest and the brain sleep to enable the organism to remove the accumulating surplus of water. Normal sleep is produced by the increase of water in the nerve cells. Some nerve tracts are less soaked than others and recover more quickly, hence partial cerebral activity and dreams. The winter and summer sleep of animals is said to be due to the presence of relatively greater amounts of aqueous vapor in the air, which hinders its elimination by the lungs. "Intelligence is in inverse ratio to the percentage of water in the brain and is to be measured by it, at least in the case of children."

In criticism, it may be said that other toxic products of activity, like lactic acid, urea, choline and neurine, etc., have a respectable claim to attention; that, like other theories of its class, it fails to notice the significance of the exhaustion of cell materials, which Hodge has shown to take place in normal cell activity; that it is by no means certain that the lymph which fills the spaces of the contracted cells is harmful, or that there is any noxious formation of water in nerve fibers, which Bowditch and Edes have shown to be practically unfatigable; and that it fails to notice the primary influence of habit and inhibition upon sleep, which makes sleep not simply a problem of physiology, but also of psychology.

BERGSTRÖM.

La Mémoire. J. J. VAN BIERVLIET, Professeur à l'Université de Gand. 1893, 40 pages.

The author gives a sketch of a theory of memory. He discusses briefly the modern views of the physical basis of memory; that it is the persistence of a movement, of a trace, or of a tendency to movement, in the nervous system. He believes Sergi's objection to the first theory, that the persistence of movements would bring on excessive fatigue and interfere with subsequent impressions, is valid. His own theory is a combination of the last two views, and is represented by the phrase *trace-disposition*. The theory is repeatedly illustrated by this figure: If we attach a weight to a wire of length L, which stretches it to the length L + A, and then remove it, the wire does not return to its original length L unless perfectly elastic, but suffers a permanent modification $\frac{X}{A}$. A less weight will later produce the elongation L + A, which represents the degree of excitation of the nerve cells required for consciousness. Retention depends upon the plasticity of the nervous system, which this figure typifies. Contiguity and succession are the laws of reproduction. Their physiological basis is the trace-disposition formed by the attention, which is essentially a nervous movement or excitation proceeding from one to another of simultaneous or successive impressions. Recognition, which is the essence of memory considered as a faculty of the soul, depends also upon the trace-disposition. Ideas which are recalled are characterized by an ease and facility which new impressions do not have. The basis of localization in the past is the degree of completeness and vividness of recalled images. The pathology of memory includes two groups of cases, hypermnesias and anamnesias. These are due to physiological influences which weaken or excite the nervous tissue, just as

heating the wire makes the requisite elongation L + A more easy, while cooling it makes it more difficult.

The essay is admirably clear, but is chiefly of popular interest.

BERGSTRÖM.

Lehre vom Hypnotismus. PROF. H. OBERSTEINER. 1893, pp. 62.

This really adds nothing to what all interested know, but omits much of chief importance for his purpose. It is most surprising that no mention should be made of the new movement in Sweden, which has added a practical utilization of great therapeutic value.

Hypnotism and Mesmerism and the New Witchcraft. By E. HART. London, 1893, pp. 182.

This collection of papers and addresses is sensational and anything but thorough or systematic. The author has suffered for his interest in these phenomena, and claims to have read everything, but he makes no mention of Bernheim; thinks Charcot, whose "three states" are now abandoned, has done the best work; knows nothing, that we can infer from his pages, of the scientific work upon the subject done in Germany, in Sweden, etc. We agree with him concerning Luys and expressed five years ago the same conclusion in this journal, and only find the author uninformed. His book shows how little has been done in England upon this subject. All he says from first to last is belated and thrice told to all psychologists who are versed in modern psychiatry.

Genetic Philosophy. By DAVID JAYNE HILL. (Macmillan, 1893. 382 pp. 8vo.)

The author hopes to rehabilitate philosophy by giving it a scientific foundation.

"The problem of science is never ontological, but descriptive;" and "ontology is as little a problem for philosophy as it is for science, for there is no real problem. . . . What we seek is to know the phases of being and to unify them by discovering a continuity among phenomena which shall render them one to intelligence as they are one in reality" (p. 13).

The author disapproves of Hegel's absolute idealism, and attributes Mr. Spencer's difficulties with the unknowable to the fact that his method was synthetic rather than genetic. "The genetic method . . . . consists in referring every fact to its place in the series to which it belongs." The book, therefore, consists of a series of scientific theories about the origin of matter, life, consciousness, will, morality, etc., which the author states in successive chapters, simply and clearly enough, but without doing very much to aid one in choosing between them when several conflict, or to show their metaphysical significance. But in spite of his protest against ontology, the author, like all the other writers who have made the same protest, enters the forbidden field and attempts to gather the forbidden fruit by the same old forbidden ontological method, though this method is only very partially and inadequately applied. He states, for example, that the deepest insight into the essential nature of "matter," "force" and "energy" is to be found in our own acts of will (p. 203), that inorganic processes represent "habits of the universe," and that "the universe as a whole is the expression of a 'will'" (pp. 367, 368). That "the ultimate ends towards which that will is directed" could not have been "immediately attained without the intervention of a long series of intermediaries," the author seems to regard as sufficiently

proved by the mere fact that the ends of human beings (who exist in a universe already made by another being) are realized only through progressive transformation (p. 368). The author's doctrine of personality rests upon the general "monistic" assumption that mind and matter are different aspects of a unitary being. It is as follows:

"The genesis of a personal being consists, then, not in the transmutation of physical force into psychic states, as materialism represents, but in the concentration and unification of preëxisting psychic elements, which, in their isolation are unconscious, into a conscious individual. Now my thesis is simply this: Consciousness is a complex phenomenon, not a simple state. It is made up of elements or factors which *become* consciousness in their union, but are *not* consciousness in their isolation. . . . The psychic aspect of a single brain-cell is not a consciousness, but the psychic aspects of a great many cerebral cells unified through the organic unity of an organized brain, become a consciousness" (p. 128).

What these unconscious psychic elements are, or how he knows that they exist at all, or how the organic unity of a brain can turn them into a consciousness, the author does not explain. The trouble with a "genetic philosophy" is apt to be that, as long as it is genetic, it is not philosophy, and as soon as it becomes philosophy it becomes uncritical and superficial.

H. A. A.

IMPROVEMENT AT LEIPZIG.

Former members of the first "Seminar für experimentelle Psychologie," will easily recall the upper story of the grimy "convikt," with its irregular suite of rooms, in which Professor Wundt has fostered the early growth of our science. Those quarters are now among the things that were. A modern edifice will soon occupy the site, and may possibly afford room for the psychological laboratory. Meantime Professor Wundt has taken refuge in the "Trierisches Institut," lately renovated for the accommodation of branches that were taught in the demolished convikt.

The present auditorium is inferior to the old one; it is smaller and the ceiling is too low. But the institute proper has gained by the transfer. It comprises ten rooms, all of which open on a corridor, a plan which does away with the inconvenience formerly felt of passing from room to room, at the risk of disturbing the workers. The improvement is most evident in the position of the library, which can now be reached without the trouble of rapping at half-a-dozen doors. Of the other rooms, two have been set apart for the professor and his assistant; each of the remaining seven is devoted to a special class of work, and furnished with appropriate apparatus. The dark room is considerably bettered by this arrangement, and the centering of batteries in a single apartment, from which all currents can be managed, avoids troublesome interference and loss of time. Add to these features a fine exposure in every direction, and certain provisions for comfort which not even a psychologist can forego—if the combination is not perfect, it certainly justifies the remark of Dr. Külpe: "More suitable quarters could not have been secured, had they been planned *ad hoc*."

E. PACE.

In the paper upon "Rhythm," published in this number of the JOURNAL, it was stated that sustained speech with children always became rhythmical. In support of this proposition we have to

submit the following observations made upon children by pupils of the State Normal School at Worcester, Mass. For the use of these, we are indebted to the kindness of Principal E. H. Russell:

B., age three years, had an older brother who went to school. One evening B. heard this older brother studying his arithmetic lesson and repeating the rule, "Reduce the numbers," etc. The next day B.'s mother heard him talking to himself and saying, "Renounce it by frees, an' fours, an' sevens, an' nines, and squeeze it as tight as you can." Evidently we have here a perfect rhythm. When the child attempts to repeat the rule, and being guided only by his own impulses, he selects just those words that will satisfy his rhythmical impulse.

G., age three years, heard the other children repeating the familiar incantation rhyme said when they were about to jump or run: "One to begin, two to show, three to make ready, and four to go." When G. attempted to say this to her mother, she said: "Two biggy to show, two forty go so." The child has not only caught the rhythm, but also the rhyme, and made her reproduction a type of a fairy measure.

M., age four years, watched very attentively her mother making a cake. The following day she came to the observer and commenced to repeat what proved to be the recipe for the cake which she had seen her mother making the day before. Says she: "One tea-spoonful of sugar, one cup of molasses, a spoonful of cream of soda, a little salt and some vinegar."

The rhythm is not so clear as in the previous cases, but it is impossible to read her words without feeling more or less clearly the rhythmical impulse which guided the child in the selection of her words. The subjects from which she had to select her words were ill-adapted to rhythms, and it is on this account, we believe, that the rhythm is not so perfect as in the previous cases.

THADDEUS L. BOLTON.

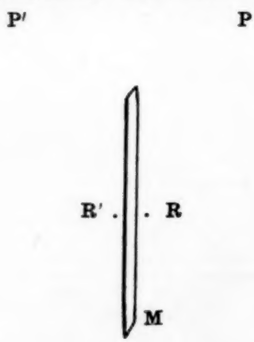
It is generally known that Pinel and Esquiral, who originated the systematic study of insanity in France, adopted the systems of Locke and Condillac as their basis; that Griesinger followed the philosophy of Herbart, although with slightly less fidelity; that Hughlings Jackson and Mercier follow Herbert Spencer in their conceptions of not only epilepsy, but of insanity generally. In education also, the influence of Herbart pervades and completely shapes nearly all that has been written in Germany concerning the theory of primary education scarcely less than did Hegelian ideas dominate theories of higher education in the days of their ascendency. In this country and in England, Spencerian ideas seem just now likely to be no less controlling. There is much evidence that the tide is now turning and that the study of children, the brain, senses and insanity is giving its concepts to philosophy.

The following interesting observation should have had a more conspicuous place.—Ed.

A New and Simple Method for Comparing the Perception of Rate of Movement in the Direct and Indirect Fields of Vision.

While sitting in my room last winter, my attention was attracted by the image of a swinging lamp in the mirror, and it then occurred to me that here was a simple method for comparing the perception of rate in the direct and indirect fields of vision. I took a position where, by looking directly at the image in the mirror, the image from the lamp itself fell on the indirect field of vision. I thus had exactly the same rate, and, provided that I placed myself so that my eye would be near the glass, almost the same extent of movement of the images. The experiment at that time was roughly made, but it showed clearly the well-known fact that of two equal rates, the one seen in the indirect field seems to be the more rapid.

I have since tested the method under more favorable circumstances, and offer it as a simple demonstrational method: Take a small, clear mirror and arrange it in the median plane immediately between the eyes, so the eye of the observer may be near the edge of it. Make a pendulum of a small string weighted with a lead ball and place it at some distance away, but near enough to the plane of the mirror to make an angle of perhaps twenty or thirty degrees with it. Swing the pendulum, not too far, nor too fast, in a direction perpendicular to the plane of the mirror. If the observer now directs his eye toward some part of the arc, through which the pendulum swings, so that the image of the moving ball will cross the point of clearest vision, the image from the mirror will fall on the indirect field and the two rates can be easily compared. The following diagram will perhaps help to show the arrangement:



(Note: P = position of the pendulum; P′ = position of images as seen in the mirror; R = position of right eye, and R′ of the left; M = mirror.)

It will be well, perhaps in most cases, to cover the ball of the pendulum with white paper. It should be noticed also that the background should offer no distraction to the attention as sources of error for the judgment.

The apparent difference in the rates will be greater when the observer directs his eye toward the pendulum, because the image from the mirror will then fall on the temporal side of the retina, which is less sensitive than the nasal side, especially in an observer whose eyes are deeply set.

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